JOURNAL SMPTE

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CBS Color-Television Staging and Lighting Practices

By RICHARD S. O'BRIEN

Color-television program production requires more stringent studio practices than does monochrome television. Camera and system adjustments must be made more precisely, the maximum scenery reflectance level must be reduced, the color balance of the studio illumination must be controlled, a higher light level must be provided and effects light ratios must be reduced. Careful attention to these aspects, in accordance with procedures outlined in this paper, together with an understanding of the fundamental difference between color and luminance contrast, makes possible satisfactory simultaneous reproduction in both color and monochrome.

COLOR TELEVISION transmission of live performances requires an extension of those studio practices which have proven effective in monochrome operation.[1,2] The color signals transmitted must provide satisfactory reproduction in monochrome as well as in color in keeping with the scanning compatibility of the present U.S. standard (National Television System Committee) color-television system.[3] This calls for the direct application of most of the well-established monochrome practices together with meticulous attention to several aspects which are especially important in color. Spectral balance, transfer characteristics, and image sharpness require the well-informed, cooperative efforts of all production personnel to achieve high quality, truly compatible color-television programs. These and other more specialized aspects are discussed in this paper under three divisions of technical production: camera operations, staging and lighting.

Color Television Camera Operation

In a color television camera, the optical image is divided by means of filters into red, green and blue images. These are converted to video signals which are handled through three parallel channels in the camera equipment. These signals are encoded, for transmission, into a luminance signal which contains all brightness information (luminance) and into a chrominance signal which contains all color information (hue and saturation). The two signals are combined by means of frequency multiplexing within the normal television broadcasting channel bandwidth. In a monochrome receiver, only the luminance signal is used. In a color receiver, the luminance and chrominance signals are decoded to obtain counterparts of the original red, green and blue signals. These are applied to a color picture tube wherein they excite red, green and blue phosphors. Combinations of these three "primary" colors enable reproduction of a wide gamut of colors.

To achieve satisfactory performance, camera facilities must be adjusted to provide proper spectral response, accurate matching of red, green and blue channel amplitude-transfer characteristics, accurate registration of the three images and sharp focus. The same basic requirements apply with surprising similarity to the two types of color studio-camera systems in use at the outset of color broadcasting. As shown in Fig. 1, one of these is the tri-tube camera in which the primary color images are applied directly to three image-orthicon tubes.[4] The other is a field-sequential camera[5] whose sequential signals are subsequently converted in the CBS-Chromacoder (a device equivalent to a tri-tube camera) into parallel, red, green and blue signals. In this paper, practices are outlined and rules stated which apply to both camera systems, specific requirements for a particular system being noted as they arise.

Spectral Balance. The red, green and blue signal voltages produced by a color-television camera are influenced by the spectral distribution of the illumination, by the spectral reflectance of the scenery surfaces, and by the spectral response of the camera tube and color-filter combinations. In order for the several cameras in a studio to produce matching images, it is necessary that the camera spectral response be carefully balanced against the spectral distribution of the studio illumination. It is the practice to adjust the relative response of the red, green and blue channels to produce equal video voltages from a gray test object placed in the normal studio illumination. To insure uniformity in amplitude-transfer characteristics, such spectral-response adjustment must be undertaken optically, ahead of the image-orthicon tubes, rather than by video-channel adjustments.

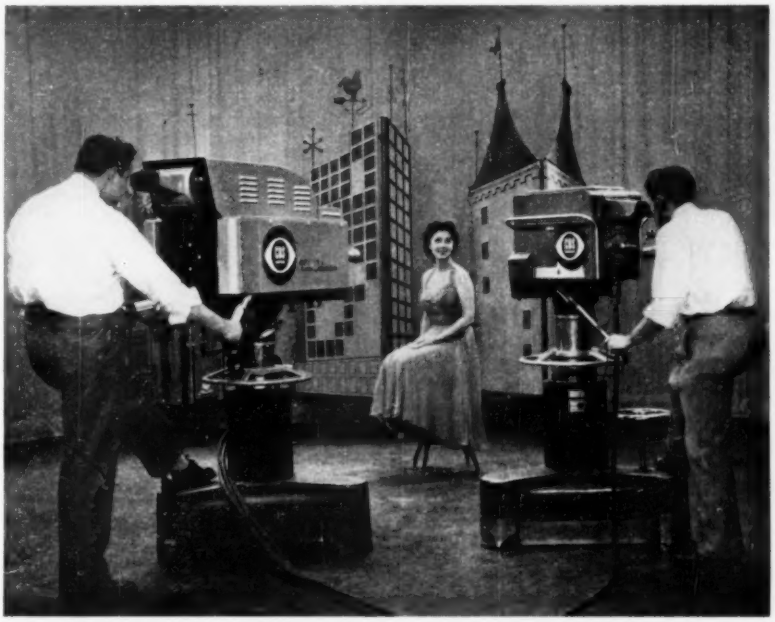


Fig. 1. A tri-tube color television camera on the left is compared with a field-sequential camera used in conjunction with the CBS-Chromacoder system. Both camera systems produce color signals conforming to the FCC color standards.

Presented on May 7, 1954, at the Society's Convention at Washington, D.C., by Richard S. O'Brien, CBS Television, 485 Madison Ave., New York 22.
(This paper was received on May 21, 1954.)

The spectral-response characteristic of presently available image-orthicon tubes, although sufficiently uniform among tubes for monochrome operation, must be individually corrected for color operation. In the tri-tube camera, each of the three tubes is required to respond to only a limited portion of the visible spectrum as shown in Fig. 2. In this case, spectral balance may be obtained by inserting neutral-density (colorless) filters in the optical paths of the more sensitive colors, until, as a convenient comparison, each channel reaches saturation at the same exposure level. Densities should be balanced to within a density step of 0.05 (10% transmission). Alternately, color-correction filters may be inserted at a point in the optical path common to all three channels, this being the practice in adjustment of field-sequential cameras.

It should be noted that a change in the color balance of the illuminant (as would be encountered in taking a studio camera outdoors) requires a different choice of neutral-density or color-correction filters. For example, to correct a camera initially adjusted for 3000 K studio illumination for use under a range of typical outdoor conditions, Wratten filters Nos. 83, 85B, 86B and the 81EF series together with a No. 2 haze filter may be found useful.

Transfer Characteristics. As implied above, uniformity in amplitude-transfer characteristics among the three channels of a color camera is essential. If the characteristic of one channel differs from the other two, the reproduced colors will vary in hue as luminance values change. For example, if the green-channel transfer were too "steep," a performer's face might change from its normal hue toward green as the performer moved into brighter light or toward magenta in shadow areas. It is especially difficult to obtain the necessary uniformity of transfer "tracking" in cameras using image orthicons, since it is well known that the transfer characteristics of these tubes are variable. As a result of the electron-redistribution process, the characteristics may follow anything from a square-root law to an essentially linear curve depending on target voltage setting, average exposure, highlight-to-average exposure ratio and other parameters. To minimize these variations the tubes must be adjusted so that highlights fall below the saturation point or "knee" in tri-tube devices rather than above as is common in monochrome operation. This minimizes electron redistribution and provides a fairly stable, almost linear, transfer, but reduces the output-signal level. This in turn requires that the close-spaced target, type-1854 tube be used in tri-tube devices in place of the familiar type 5820 to obtain a satisfactory signal-to-noise ratio.[6]

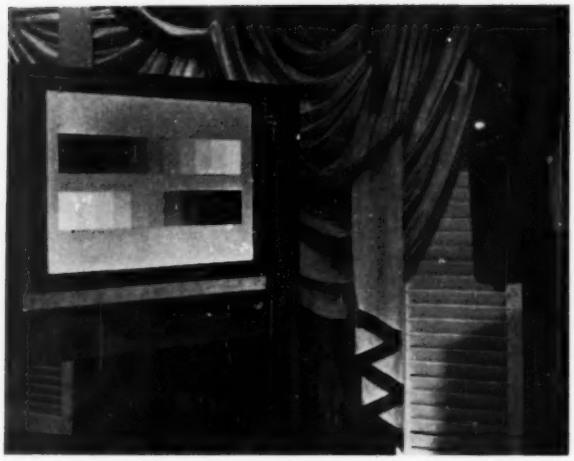


Fig. 3A. A typical, linear reflectance step gray-scale test chart placed in the normal studio illumination for observation through a camera system.

Also, to maintain the best possible signal-to-noise ratio, careful monitoring and adjustment of overall exposure must be carried on throughout a performance. For this purpose, a remote-controlled iris or equivalent must be provided in the common optical path of each camera.

As outlined in the preceding section, the three channels of a color camera may be adjusted to reach saturation at the same exposure level (common-path iris adjustment). In making this adjustment, the target voltages of the three image orthicons must first be carefully set by means of a voltmeter to a chosen potential above cutoff. Higher voltages (e.g., 3.0 v) than used in monochrome are recommended to further minimize electron redistribution effects. Saturation may be observed by noting the concurrence of compression of the top steps of the signals from a gray-scale test chart (see Fig. 3A) as the exposure is varied equally in the three channels. After this adjustment is made, the top steps may be set just below saturation and the shape of the step-wave signal obtained from the gray scale observed on the camera-control waveform monitor. The monitor should include an electronic gating system whereby the three camera channel signals may be "overlaid" or placed side by side as in Fig. 3B to facilitate tracking adjustment. Small departures at lower levels may be compensated for by slight readjustment of one or two of the target voltages, and

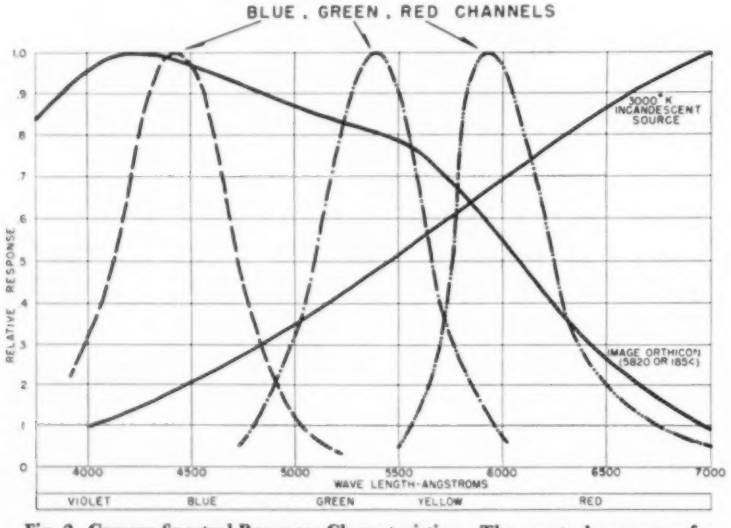


Fig. 2. Camera Spectral Response Characteristics. The spectral response of a typical image-orthicon camera tube is essentially complementary to the spectral energy distribution of a typical incandescent source as shown by the solid-line curves. The relative response of the taking primary channels of a tri-tube camera are shown by the broken-line curves.

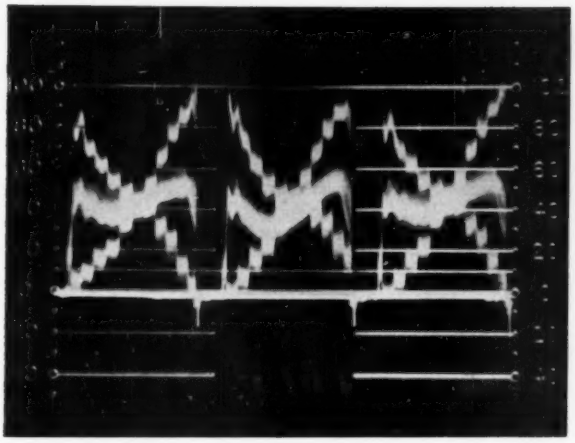


Fig. 3B. The red, blue and green video signals from the chart shown in Fig. 3A as seen on a gated waveform display. Color-balancing filters are inserted to cause the top steps of each signal to reach saturation concurrently.

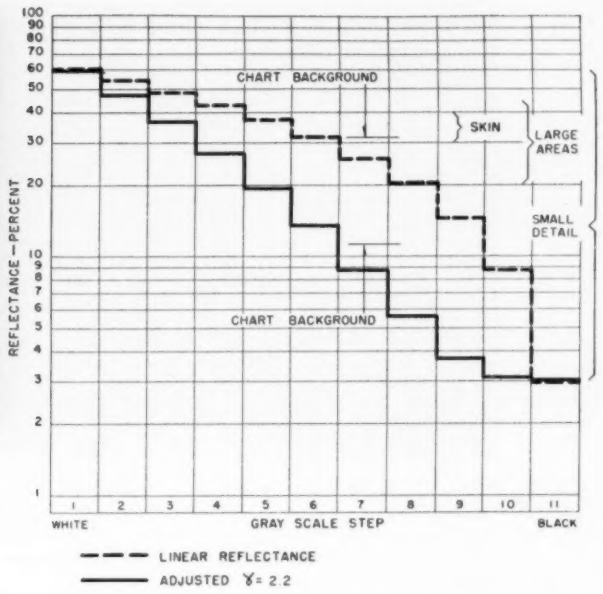


Fig. 4. Gray Scale for Color Camera Adjustment. The broken-line scale is a linear reflectance gray scale suitable for camera adjustment. The solid-line gray scale is arranged to produce a linear wave-form display after gamma correction and is recommended for use in scenery luminous reflectance calibration.

by careful adjustment of parameters affecting flatness of fields and shading. Large departures require selection of one or more replacement image-orthicon tubes. Shading adjustments must be made to achieve flat shading on neutral gray backgrounds of 15 to 20% luminance reflectance and also to achieve symmetry of the crossed gray-scale waveforms.

As noted, the tri-tube camera transfer characteristic is essentially linear. Thus, a linear reflectance gray scale, Fig. 4, is desirable as it provides an almost linear step-wave display on the camera waveform monitor. However, it is a specification of the National Television System Committee (NTSC) that the camera system be corrected to an overall gamma of 0.45 (1/2.2) to compensate for the nonlinearity of the reproducing picture tube. A gray scale which follows the inverse of this law (gamma = 2.2) is useful where a linear waveform display is desired at a point in the system which follows the electrical gamma-correction device. This scale is also of value in scenery-reflectance calibration and in direct visual observation on a picture monitor because its steps appear nearly equal to the eye. Observation of either of these gray scales on a well-adjusted color monitor provides a critical check of transfer tracking which can be made quickly and easily. Proper reproduction of a neutral gray scale is among the most severe tests for transfer tracking in a color system.

In connection with overall system gamma, it is to be noted that the unity gamma relation between input light and output light values which is theoretically necessary for the best color fidelity produces rather low contrast, washed-out monochrome reproduction. As a compromise, an overall gamma of up to 1.5 may be used requiring an electrical gamma correction of 0.7 to 0.8.

Image Resolution. The three images in a tri-tube device must be held in excellent registration to achieve good resolution and to avoid color fringing. In making adjustments it is common, first to adjust the scanning size and linearity of the green channel which contributes the largest portion of fine detail information to the luminance signal. The red and the blue channels are then adjusted to overlay the green channel throughout the raster. As an indication of the accuracy required, Fig. 5 shows that a 0.1% horizontal misregistration of the red channel results in a 20% reduction in luminance signal response for a 280-line resolution test pattern, while a 0.5% misregistration produces a loss of 30% at line numbers 75 and 255. The rectan-

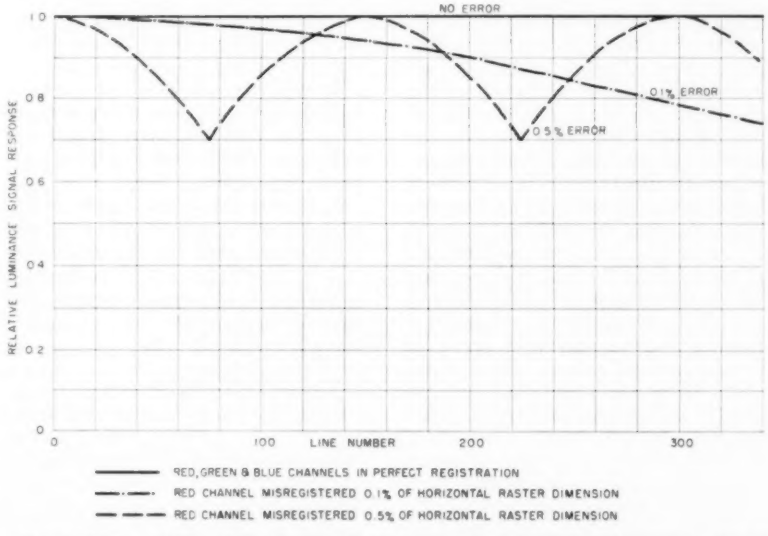


Fig. 5. Effect of Misregistration on Resolution. The response of tri-image devices to fine detail is influenced by the accuracy with which the three images are scanned in proper registration. Ideal aperture correction is assumed in this plot to clearly show the relative loss in detail response caused by misregistration.

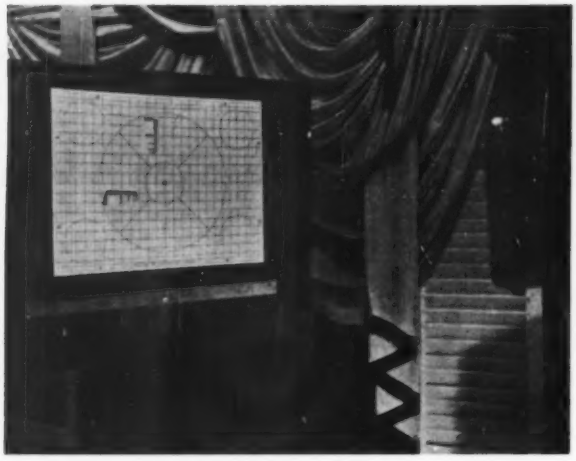


Fig. 6. Coarse camera registration is accomplished by overlaying the three images of the rectangular grid pattern. Fine adjustment must seek to obtain the maximum resolution on the fan-shaped resolution wedge over the major portion of the raster.

gular grid pattern on the test chart shown in Fig. 6, may be used for coarse adjustments, the lines being 0.031 in. wide (whereas 0.1% is only 0.024 in. on the chart). The resolution wedges, however, must be used for fine adjustment, resolution of at least 450 lines being necessary. Registration adjustments may be observed on monochrome monitors, the camera monitoring equipment being equipped if possible to display camera channels singly, in pairs or all superimposed.

The same procedure applies to the tri-tube portion of the Chromacoder, the test chart being transmitted to the translation unit through a sequential camera.

In addition to the loss in resolution incurred by slight misregistration, further degradation occurs in tri-tube devices from the operation of image orthicons with highlights below the knee. Operation above the knee which is normal in monochrome applications tends to enhance edge contrasts through electron redistribution. These enhancing effects cannot be achieved in tri-tube color devices, because the conditions of operation whereby they are obtained also produce intolerable nonlinearity and variability in transfer characteristics.

In place of these effects, the effective sharpness of a color camera is improved by the introduction of aperture correction which boosts the higher video frequencies. The intent of aperture correction is to compensate for the inherent loss in fine detail which occurs when the image is scanned by an electron beam having a diameter (effective scanning aperture) which is only slightly smaller than the image detail structure. Over and above correct adjustment of the aperture correction amplifiers, it is essential in color camera operation that all optical and electrical focus adjustments be monitored with great care.

Suggested Camera Operating Rules.

1. Operate image orthicons in tri-tube devices below the "knee," riding exposure control to hold highlights at the proper level.

2. Accurately set image-orthicon target-screen voltages to equal voltages above cut-off, (e.g., 3.0 v) varying from this only slightly to improve transfer-characteristic matching as determined by reproduction of a gray-scale chart.

3. Balance exposures at the image orthicon "knee" on the three color channels to be coincident within a 0.05 density step.

4. Adjust for flat shading of backgrounds on a gray surface having a 15 to 20% luminance reflectance value.

5. Adjust image registration prior to making final transfer-characteristic adjustments, using the green channel as a reference. Adjust to obtain detail resolution to at least 450 lines.

6. To compensate for limited resolution, be meticulous in adjusting and monitoring optical and electrical focus.

7. To the greatest possible extent make all adjustments correctly in advance of an operation and make only emergency changes during operation.

Color Television Staging

Whereas it is an objective of camera operation to generate signals which faithfully reproduce the hue, saturation and brightness of the original scene, it is the purpose of staging and lighting to achieve prescribed artistic effects. Intentional distortions may be required to obtain a certain effect. For example, enhancement of color contrasts may be required, as is true also in photography and pictorial painting, to create the illusion of a three-dimensional scene on a flat viewing surface. The practice of such compensations requires a mutual understanding of the problems and close cooperation among technical, staging and lighting personnel so that adjustments may be made in the most appropriate way.

Fortunately, the more realistic appearance of color reproduction makes it somewhat easier to predict the end result than in the case of monochrome. However, the idiosyncrasies of the television facilities detract somewhat from this predictability and call for certain allowances in staging practice. Specifically to be avoided are: certain colors which are reproduced inaccurately, conditions wherein colored backgrounds interact on foreground objects and excessively fine detail which is beyond the capability of the system. In addition, there is the ever-present requirement that a balance be achieved between color contrast and luminance contrast to insure satisfactory reproduction in monochrome as well as in color. Proper solutions to these and other staging problems require an understanding of the manner whereby staging materials reflect light of various wavelengths to produce sensations of hue, saturation and luminance.

Reflectance of Surfaces. An opaque surface in a scene appears to have color as a result of the particular way in which it reflects light. Visible light is known to include radiant energy components having wavelengths ranging from 4000 to 7000 A (A = Angstrom unit = 0.1 mμ = 1/4,000,000,000 in.). If these single-wavelength components were observed individually, they would produce color sensations ranging from violet (about 4000 A) through blue, cyan, green, yellow and orange to red (above 6000 A) — the so-called spectral colors. If the light reflected from a surface contains relatively stronger components in a particular region of the spectrum, it too may produce the sensation of a characteristic color or hue. Such a hue may be identified in terms of the particular or dominant wavelength of a single component which would produce the same sensation. The degree to which the actual reflected light components are concentrated near the dominant wavelength determines the saturation. A highly saturated color has a relatively narrow spectral-energy distribution and may be thought of as having a high purity of the dominant wavelength. The total strength of the reflected light determines its brightness or luminance value.

Luminance value is measured with reference to the amount of radiant energy which falls within the spectral region of the standard luminosity curve. This

curve, included in Fig. 7, has been chosen by international agreement to represent a standardized spectral-sensitivity characteristic for the human eye. In monochrome television, the camera spectral sensitivity corresponds approximately to this curve, and the camera output signal thus provides a direct measure of luminance values. In color television, additional steps are involved. To obtain a measure of the hue and saturation of colored surfaces, the color-camera response is broken into relatively narrow portions of the spectrum as indicated in Fig. 2. The relative amplitudes of the video signals obtained from each of these three primary color regions are then compared to obtain video signals representing color differences and thus conveying hue and saturation information. Also, the signals from the three channels are added together in proportions established by their spectral positions on the standard luminosity curve to form a video luminance signal. This luminance signal is essentially similar to that generated directly by a monochrome camera. It is to be noted that the camera basic spectral response combined with the spectral distribution of the incident light may be assumed for the present to be uniformly balanced throughout the spectrum, the staging problem being concerned with the spectral reflectance of surfaces.

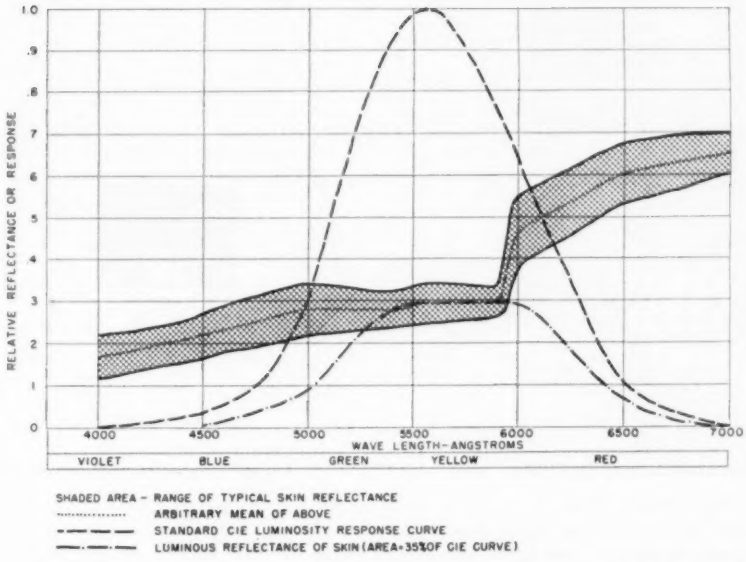


Fig. 7. Spectral and Luminous Reflectance of Skin. The spectral reflectance of human skin varies among individuals, among different areas of each individual and as a function of exposure to the sun. The range shown is representative, but not all inclusive. The luminous reflectance of any surface is its relative reflecting efficiency as measured against the standard luminosity curve and as compared to a perfect reflector.

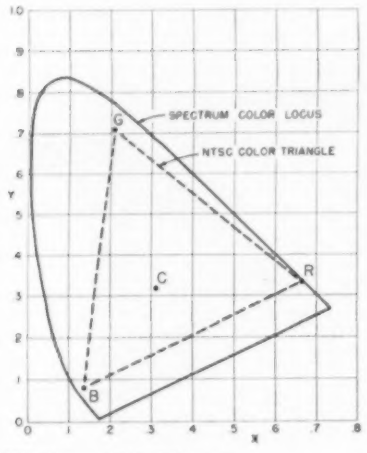
Selection of Colored Surfaces. The selection of materials and paints for a given scene is complicated by the divergent requirements of color and monochrome reproduction. Color reproduction calls for a reduced range of luminance values to allow scope for the color-signal components. In this case, the lack of luminance contrast is more than compensated by color contrast, i.e., differences in hue and saturation. In monochrome reproduction of the same signal, however, the benefits of the color contrasts are not present and the reduced luminance range results in a relatively low-contrast image. This conflict between color and monochrome contrast will be a problem as long as monochrome receivers are in use. It may be resolved by using somewhat desaturated colors, and by making up for reduced large-area luminance values by including small, bright, white highlights in the scene.

As in the case of monochrome studio practice, the luminance-reflectance scale is chosen with respect to the typical reflectance of a performer's skin. The reflectance of skin differs for various spectral wavelengths as shown in Fig. 7. That is, it has color — a desaturated yellow-pink. However, its luminance value of reflectance, measured against the luminosity curve as shown, for typical fair-skinned individuals falls between 30 and 40%. The gray scale shown by the solid line in Fig. 4 has been chosen to have its top step at about 60%, the entire scale having been shifted downward as compared to that recommended for monochrome. Large areas of the scene should not be allowed to exceed this 60% luminance reflectance and preferably should be held between 20% and 50%, a range of $2\frac{1}{2}$ to 1. This applies to areas which appear larger than about one-quarter of the area of a performer's face in the camera image. This restriction is necessary in order to insure that overexposure of the camera tubes may be avoided and that there will be ample headroom available for superimposing the chrominance signal on the luminance component in transmission. However, it is desirable to allow small white highlights to exceed this value in order to enhance the luminance contrast in monochrome reproduction.

Scenic design is facilitated if a catalog of precalibrated samples of scenery materials is made. The samples may be calibrated for luminance reflectance against the color gray scale as observed through the camera system after the manner outlined for monochrome.[2] In making such calibration, the encoded signal should be observed on a monochrome monitor.

Precalibration of samples with respect to their color aspects, hue and saturation, is a little more cumbersome because of the great number of possible combinations of these factors. However, it is possible, by means of an electronic, vector display of an encoded color signal to obtain numerical quantities which specify hue and saturation. Hue is expressed as a vector angle, saturation, as an amplitude in a display which provides a close analogy to the familiar ICI (International Commission on Illumination) chromaticity diagram as shown in Fig. 8. An alternative method for precalibration could be evolved using one of several commercially available, material color standards as a reference for comparison. In the Munsell System, for example, letter and number designations are assigned to over 400 samples covering a wide gamut of hue and saturation and of luminance values as well.[7,8] Actually, if luminance values are held within bounds, very little restriction on hue exists and saturations need be kept low in only a few cases. At this stage of the art, it is felt that any elaborate system for color precalibration is unnecessary, so long as luminance reflectance values are properly controlled. Only a few colors may cause trouble, particularly those having both high luminance and high saturation such as yellows and cyans and occasionally those having very low luminance such as dark blues and reds. Such few colors may be noted and used with due care as to luminance conditions.

Background Surfaces. In large area backgrounds, it is important to avoid high luminance values in highly saturated colors, particularly those having a hue near one of the three camera primaries or its complement. A predominance of energy in one color may



ICI Chromaticity Diagram

Vector Display of Encoded Signal

Fig. 8. The chrominance portion of an encoded signal obtained from a sample of material (e.g., a green color chip) when viewed on a vector display shows hue as a vector angle and saturation as a radial distance. The NTSC-specified receiver primaries are plotted in their correct positions on this display and also on the ICI chromaticity diagram to show the similarity of the two displays.

cause overexposure and consequent shift in the transfer characteristic in the corresponding camera channel (or during the corresponding period in a sequential camera). The effect is to cause foreground objects to shift in hue as they are moved in front of the background color area or as the camera-lens acceptance angle is changed, changing the relative area covered by the colored background in the final image. A case to be particularly avoided is a high-luminance, high-saturation cyan background which, if it overexposes the green and blue camera channels, may cause faces to turn red. This electronic effect is independent of direct optical contamination of foreground object color by light reflected from nearby colored surfaces.

The use of desaturated or pastel colors, matte surfaces, and medium luminance values will solve part of the background problem. The inclusion of patterns or pictorial details in which a more or less equal amount of reflectance is provided in the three primary colors also will help. Scenic backdrops which include well-distributed, desaturated, primary colors usually reproduce well in both color and monochrome. Excessively busy backgrounds should, of course, be avoided. In general, tan, beige or pink areas reproduce satisfactorily and have a minimum effect on the most important foreground object — a performer's face. Uniform gray areas which contain equal amounts of energy in the three primaries are somewhat difficult to use because slight departures from an intended neutral gray are easily noted by a viewer. Gray may be used in smaller areas. Low key effects may be used if the dark areas are partially filled in with objects or areas providing a reasonably high though not necessarily continuous reflectance in all three primary color regions. Outdoor scenes should avoid using the open sky with its very high luminance as a background, a building, trees or other less luminous areas being more satisfactory.

Clothing and Make-up. Clothing, which appears adjacent to a performer's skin is subject to the same general considerations as backgrounds. Where the clothing is intended to be colored, care must be taken to avoid saturated colors which might cause differential overexposure and adverse effects on adjacent skin areas. Where clothing is intended to appear white, "tattle-tale gray" must be substituted for the light blue or tan garments used to achieve reduced luminance in monochrome practice. The "white" clothing should have a luminance reflectance which does not exceed the 60% step of the gray scale. With respect to the texture of woven material, the swirl pattern which results from the beat between the texture pattern and the camera scanning lines may show up in distracting rainbow effects in the color system. To avoid this, the material may be replaced or the picture composition altered to change the relative dimensions of the texture as compared to the camera raster.

In addition to being influenced by surrounding areas in a scene, the reproduction of skin color is complicated by the variation of the spectral reflectance of skin among individuals (see Fig. 7). Also, the color will vary from one part of a person to another depending on sun tan and other factors. Thus, the objectives of make-up for color television are to make all visible areas of each performer look the same and to achieve reasonable uniformity of coloration among the several performers. The principal correction required among individuals involves slight variations along a green-to-magenta axis. The amount of make-up required is normally small enough so that the appearance of the performer is quite natural on direct observation. In applying make-up, any direct visual judgments should be done under illumination of the same type and color balance as that used in the studio. A final, on-camera observation is desirable.

Identifiable Surfaces. The familiar and easily identified packages and trademarks of well-known products may require particular attention to insure their reproduction with good color fidelity. In some cases, retouching may be required to achieve the desired final result. A number of packages include high-luminance white areas which may have to be toned down toward gray to conform to the luminance range limitations. Colors can usually be accommodated satisfactorily although in some cases it will be desirable to raise or lower the relative luminance of a particular color by retouching with black or white paint. In addition to the use of direct retouching of the packages, slight errors in color rendition can sometimes be rectified by the use of color filters on the camera lens or on the light source. This is, of course, restricted to cases where the package is viewed alone. In general, it is not advisable to attempt corrections by camera adjustment although this, too, may be required in special cases.

Image Sharpness. It has been recommended in monochrome practice[1] that close-up views be used where facial or other fine detail is important. In color, the need for this is even greater because the system imposes a slightly lower limiting resolution than that of monochrome. The present-day camera and receiver equipment further degrades signal transmission, the overall resolution limit being about 15% lower in typical operation than for the monochrome system. This figure should be kept in mind as a guide to how much larger a given object should be made in the final image to insure detail rendition commensurate with that expected in the familiar monochrome system. It should also be noted that resolution and sharpness will be further enhanced if color saturation is kept low, particularly for viewing on monochrome receivers.

Slight additional detail degradation will accompany motion because of relatively long storage time in the camera tubes (operating without redistribution) and because of the slow decay times of certain of the color picture-tube phosphors. Another factor relating to image sharpness is the practice of opening the

camera lens aperture one stop wider than in the case of monochrome, to compensate partially for the losses in camera sensitivity. This causes a reduction in depth of focus making it a more critical matter to keep the camera in focus and reducing the depth of playing area which may be kept in focus simultaneously. The increased importance of this problem makes it desirable to examine proposed scenes with a view to using shallow playing areas.

Suggested Staging Rules.

1. For optimum color reproduction, large area surfaces should have a luminance reflectance not over 60% and preferably between 20% and 50%.
2. Small white highlights may be allowed to exceed these limits in order to achieve acceptable luminance contrast for monochrome viewing.
3. Samples of colored materials and paints should be precalibrated as to luminance value against a gray scale.
4. Backgrounds should be low in saturation, matte-surfaced and of medium luminance. Patterns or pictorial material which provide reflectance in all three primary colors should be distributed through a scene — particularly in low-key backgrounds.
5. White clothing must not be worn, gray shirts should be used to represent white, in place of blues or tans used in monochrome practice.
6. Make-up should be judged "on-camera" or at least under lighting of the same type used in the studio. Care should be taken to make all exposed skin match.
7. Identifiable product packages may require slight corrective retouching, particularly in high luminance whites, in order to reproduce correctly in both color and monochrome.
8. Close-up shots should be tightened about 15% as compared to monochrome to retain equivalent fine detail, when it is desired, in the image. Also, scenes may have to be designed with shallow playing areas.

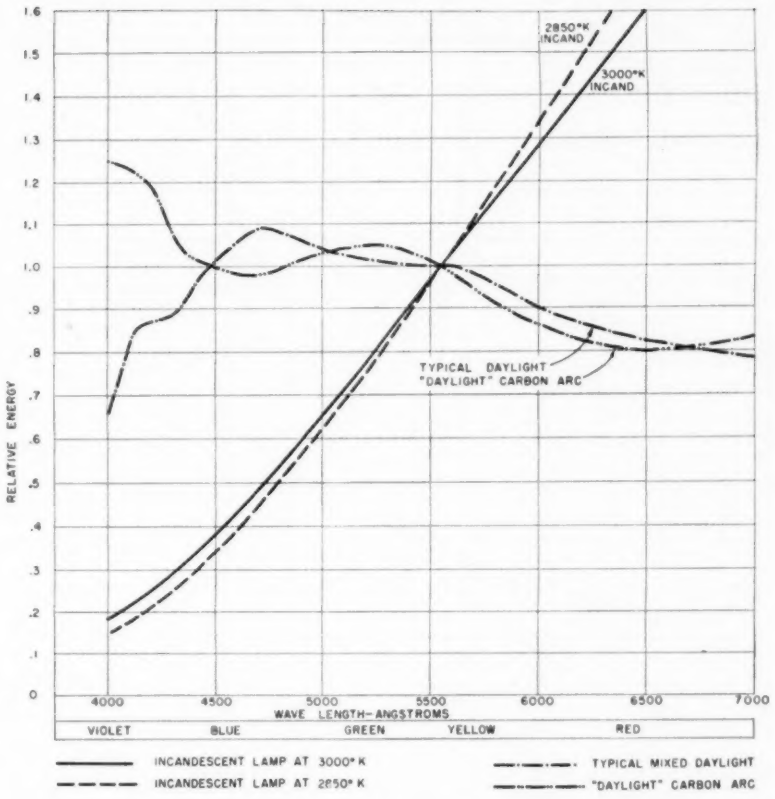


Fig. 9. Spectral Energy Distribution of Typical Light Sources. The spectral energy distribution of the typical light sources shown are sufficiently smooth for use in color-television lighting. Intermixture of incandescent lamps and carbon arcs or daylight requires filter-correction of one of the two sources.

Color Television Lighting

As noted, the hue, saturation and luminance signals derived from a colored surface depend on the character of the incident light as well as the reflectance characteristics of the surface itself. Color television reproduction, like color photography, is influenced by the color quality of the light used in the studio. Whereas, in monochrome television, the color balance of the studio lighting has only secondary effects on the gray rendition of colored objects, in color television, variations in illuminant color can result in drastic changes in color reproduction. Therefore, in addition to the careful adjustment of the base light levels and effects-to-base light ratios, particular care must be given to the nature of the light source itself. The problems, however, are in no way mysterious and are amenable to straightforward solutions.

Sources of Light. Sources of light in color television studios must be capable of producing relatively high illumination levels, must be easily adjusted to the same color balance among different units and, above all, must have a spectral energy distribution which follows a smooth curve. The narrow, high-amplitude peaks which are contributed by the low-pressure mercury arc which excites the phosphor in fluorescent lamps, for example, can cause serious distortion in the rendition of certain colors. Although fluorescent lamps have been used in some color television demonstrations and for industrial applications, sharply peaked, discontinuous spectra of this type should be avoided where color fidelity is important.

Sources which have sufficiently smooth spectral-energy distributions include incandescent lamps, sunlight and some carbon arcs. Representative spectra for these sources are compared in Fig. 9. If sources having widely differing spectral distribution are to be intermixed, they must, of course, be corrected by means of filters to match in relative energy level throughout the visible spectrum. Incandescent sources are the most suitable for present-day television-studio operation because, in addition to a smooth spectrum, they are convenient to handle and maintain, they are readily available in a wide range of sizes and types and they may be easily adjusted to obtain a spectral match among units.

Incandescent Lamps. Although the spectral distribution of incandescent lamps follows a smooth curve, there is not an equal amount of energy in all parts of the spectrum. In general, the energy is higher at the red end of the spectrum and includes components in the invisible, infrared region. There is, however, ample relative energy in the blue end of the spectrum to enable color correction to be introduced optically at the camera to give the effect of an equal energy distribution. The correction is facilitated because the camera pickup tube has its highest sensitivity in the blue region so that the camera response and the illuminant distribution are somewhat complementary (Fig. 2). It is of greatest importance that the spectral distribution be made essentially the same for all light sources so that the correction introduced

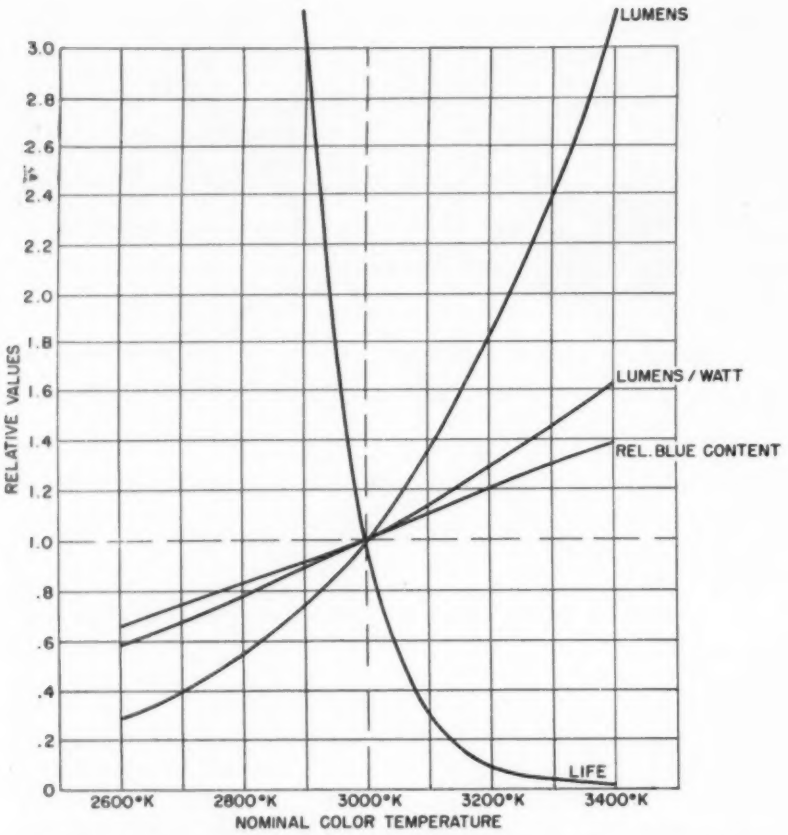


Fig. 10. Incandescent Lamp Parameters. Relative values of incandescent-lamp parameters are arbitrarily set at unity for a nominal lamp color temperature of 3000 K to show the relations between total light output (lumens), efficiency (lumens/watt), the relative energy at the dominant wavelength of the camera blue primary compared to that at the red primary (relative blue content) and (life) as the lamp color temperature is varied.

at the camera will be usable throughout the studio area. This places some restrictions on the choice of lamps and on dimming adjustments.

Light is produced in an incandescent lamp by passing an electrical current through a small filament of tungsten wire, heating the wire to the point where it glows. As the current flow is increased, the heat of the filament is increased and the metal progresses from being "red-hot" to being "white-hot." As it is characteristic for the spectral distribution of the radiated energy of glowing, incandescent material to follow a discrete curve for any particular temperature of the material, it is common practice to describe energy spectra for incandescent lamps in terms of "color-temperature." Thus, a 2850 K lamp has a spectrum similar to that which would be produced by a sample of idealized radiating material heated to a temperature of 2850 K. The Kelvin scale of temperature has degree units equal to those of the Centigrade scale, but has its zero at −273 C. As the temperature is increased, the relative energy level in the blue region increases somewhat, causing the progression from a reddish toward a whiter color balance as noted above.

There are intrinsic relations for a given size of lamp (size and shape of filament wire) among the total light output, the efficiency, the color temperature (and thus spectral distribution) and the life of the lamp.[9] These relations are plotted with respect to color temperature in Fig. 10, from which it is apparent that the higher color-temperature lamps (such as the 3200 K color photography series) produce more and somewhat "whiter" light with a drastically reduced life. In color television studios there appears to be no reason to use other than the general service series of lamps which range from 2870 K to 3000 K in color temperature, there being ample blue energy present to enable the camera to be properly color balanced even with color temperatures as low as 2300 K. The important point is to hold all lamps in a studio within a limited range which permits them to be intermixed.

As a rule of thumb, the color temperature of a lamp may be assumed to change about 10 K for every volt departure from normal applied line voltage (120 v). In practice, it is possible to intermix lamps which are within a range of ±100 K, requiring voltage to be held within ±10 v for a given type of lamp. This allows a reasonable range of dimming adjustment for purposes of balancing levels and ratios, a 10-v reduction in applied voltage corresponding to a 30% reduction in light level. However, greater amounts of dimming adjustment should be used sparingly because they produce a large enough change in color balance to be noticed through the television system. The relative spectral energy distributions for several lamp operating conditions are compared in Fig. 11. Dimmer adjustments may be used within limits to balance out differences among lamps of different wattage ratings which have different normal color temperatures, to compensate for aging effects (a drop off of as much as 50° sometimes taking place), or to compensate for color changes introduced by the fixtures (as much as ±50°). In critical work, such adjustments may be made by noting relative photocell meter readings through red and blue filters, such as Wratten No. 25, red; and No. 47, blue. Color-temperature meters have been described[10] which provide a convenient, calibrated means for making this type of measurement. Meters capable of reading red, green and blue spectral reflectance are useful where these three regions of the spectrum are desired to be measured.[11]

Some improvement in light-to-heat energy ratio on the stage area may be obtained by fitting all incandescent fixtures with infrared absorbing filters. For example, Aklo #3962, cut into 1-in. strips and held loosely in frames to prevent fracture from heat-induced strains is suitable for this purpose. The nuisance of the added element on each light fixture must be weighed against the slight improvement in comfort for the performers. There is no advantage with respect to camera performance.

Lighting Levels. The primary color filters in the color television camera reduce the amount of light energy reaching the camera tube for any one color to less than $\frac{1}{3}$ the amount which reaches the tube in a monochrome camera. Additional losses occur in added optical elements and in the compensating filters used to achieve balanced spectral response. The net result is to make the color camera sensitivity for correct exposure conditions about $\frac{1}{8}$ that of a monochrome camera. This applies to both the Chromacoder field-sequential camera and to the tri-tube camera. Although a less sensitive pickup tube is used in the latter, it is operated at a relatively lower exposure with respect to its saturation point and thus requires a similar light level. It is

recommended that about half of this decrease in sensitivity be made up by opening the camera lens one stop and the remainder by increasing the light level by a factor of 2.5:1. As compared to the recommended monochrome lighting level[1] of 120 ±10 lm/sq ft (footcandles) with a lens stop of $f/8$ the color lighting level should be 300 ± 20 lm/sq ft with a lens stop of $f/5.6$. For areas which are intended to be reproduced similarly, the tolerance should be observed over the entire playing area including the background and due consideration should be given to uniformity for all camera angles.

It is worth noting that this increase in base-light level requires an increase from 60 w/sq ft of actual studio playing area to 150 w/sq ft for color. It is suggested that a minimum of 50 w/sq ft of total studio floor area be provided in color studios, playing area normally utilizing $\frac{1}{3}$ of the total floor space.

Effects light should be employed as in monochrome except that ratios of effects-light components such as back light, modeling light, key light and eye light to the base light must be reduced slightly over those used for monochrome although at some sacrifice in the contrast of the monochrome reproduction from the color signal. Compromises must be made in individual cases on an artistic-judgment basis, observing the result on both monochrome and color-picture monitors. As target values for effects-light components, it is recommended that back light be set between $\frac{1}{2}$ and 1 times base light and that modeling light, key light or other side light be set between 1 and $1\frac{1}{2}$ times base light. Eye light and other specular highlight sources must be adjusted to achieve the desired effect, small, sharp highlights serving to enhance the apparent monochrome contrast. Care must be taken to maintain the level of the light reflected from background areas within a range from $\frac{2}{3}$ to 1 times the light reflected from performers' faces, requiring that the incident light level on the background be about equal to that on the performer for normal scenes.

The relative incident light levels may be measured with ordinary photoelectric exposure meters in the manner used in monochrome television. That is, base light should be measured first and the effects lights added and measured individually. In cases where unusual care is required, supplementary measurements of reflected light may be made, the ratio of the lightest to the darkest areas of the scene being held to not exceed 5:1 for large areas and 20:1 for small areas.

Special Effects. The possibilities for special effects in color lighting are almost unlimited. The few precautions which must be observed include: (1) Effects should be avoided which, although satisfactory in color, are meaningless or even confusing in monochrome reproduction; (2) Care should be taken to prevent purposely colored effects-light from optically spilling into adjacent areas of the scene thus distorting the color rendition of familiar objects; (3) As in the case of staging, strong saturated background colors which might interact on camera tube transfer tracking should be avoided.

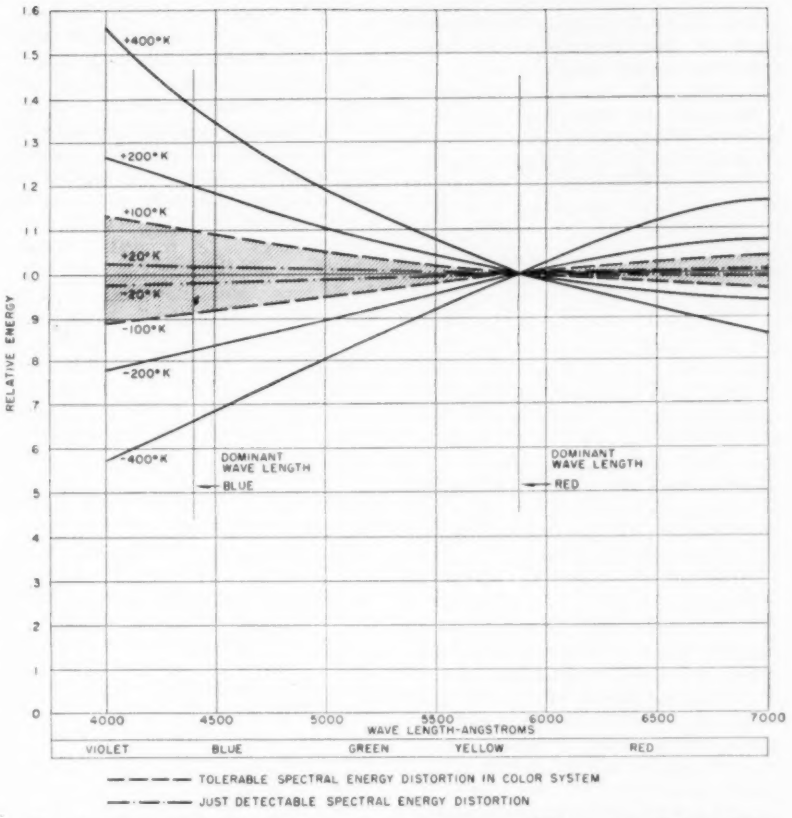


Fig. 11. Spectral Distribution vs. Color Temperature. The curves of the relative spectral distribution of incandescent lamps as a function of color temperature have been normalized to unity at the dominant wavelength of the camera, red-taking primary and plotted so the camera response is equally balanced throughout the spectrum for the reference value. The minimum detectable variation refers to carefully controlled test conditions. The tolerable distortion limits correspond to conditions found not noticeable in typical operation.

Fixtures equipped with dyed-gelatin filters (stage "gelatins") may be used to provide readily changed background colors on a gray cyclorama backdrop. Three sets of fixtures fitted with red, green and blue gelatins and so positioned as to have overlaying coverages, may be differentially dimmed to produce almost any desired color at any desired level of luminance. It is to be noted that there is almost no shift in color as a filtered lamp is dimmed because the filter passes only a very limited bandwidth within which lamp spectrum variations are negligible. Dimming of color-filtered lamps may, therefore, be done without restriction.

Low key effects may be handled by the color television system although it is desirable to avoid large dark areas because very slight differences in camera shading signals may show up as color-shading effects. A "fade-to-black" may, if shading and setup adjustments are not very precisely made, become a fade-to-magenta; on the other hand, if camera adjustment is correctly done, the tri-tube camera will be less subject to the spurious effects often encountered in monochrome operation. To be safe, lighting and staging should be arranged to insure the presence of at least some luminous area in all parts of the picture raster. The dark areas may be allowed to go as low as 100 lm/sq ft in incident light.

Spotlight effects can be used if they are adjusted to produce a total front light—including base light — which does not exceed $1\frac{1}{2}$ times the normal base-light level. Also, the background which appears behind the performer in the picture should be lighted to have a reflected luminance between $\frac{2}{3}$ and 1 times that of the performer's face. Arc spotlights, of course, must be color corrected with filters or gelatins to produce a color match, as observed visually, with the incandes-

cent lamps used in the studio unless a colored effect is desired. The carbon-flame arc and high-intensity arc have sufficiently uniform spectra to make such correction and intermixing possible.[12]

Similarly, the light from rear-projection devices using arc lamps must normally be filtered to match the studio illumination in color balance. As an example, a 90-amp carbon-arc slide projector used with a neutral screen has been found to be satisfactorily corrected with the equivalent of a Wratten No. 86B filter. In rear projection, arc sources will generally be required for the coverage of any area larger than 20 sq ft because of the high ambient studio light and the need to balance foreground and rear-projection luminance levels more closely for color. Precautions must be taken to obtain steady, flicker-free illumination from arc sources. Additional color correction will often be required to obtain the desired effect from any particular color slide being used.

Suggested Lighting Rules.

1. Use light sources which have smooth spectral energy distribution curves, such as incandescent lamps.
2. The standard service series of incandescent lamps, having spectral distributions corresponding to color temperatures of between 2800 K and 3000 K, are recommended.
3. Maintain the color balance among source units and fixtures within ±100 K (corresponding to ±10 v).
4. Do not dim unfiltered lamps to lower than 90% of rated voltage (which corresponds to 70% of rated lumen output).
5. Use a base-light level of 300 ±10 lm/sq ft.
6. Use a back-light level of ½ to 1 times the base-light level.
7. Use a side-light level (modeling or key) of 1 to 1½ times base-light level.
8. Measure reflected-luminance levels with a spot brightness meter in critical work and hold large areas of the scene within a 5:1 range.
9. Use "gelatin" filters on three intermixed sets of background or cyclorama lighting fixtures to obtain a wide gamut of background colors.
10. Correct with light filters the light from carbon arcs used in rear projection or spotlights to match the light from the incandescent studio lights.

Summary

As compared to monochrome practices, color-television live-studio operation requires a much more careful and critical approach. Cameras and associated equipment must be carefully adjusted as to spectral response, transfer characteristics, tri-channel registration and resolution. Staging must be designed to make the most out of the present facilities in order to produce artistic results in both color and monochrome. Luminance values must be relatively lower than in monochrome studios and color saturation must be played down in large areas. However, color can be used almost without limit in smaller areas and objects. Lighting, in turn, must be controlled as to spectral energy distribution and a higher and more evenly distributed base level must be provided. Effects-light ratios are slightly reduced. Dimming is restricted somewhat except in the case of color-filtered fixtures used for special effects. Almost unlimited color effects are possible through combinations of staging and lighting control so long as the transmitted signal provides the luminance contrast required for monochrome reproduction as well as the color contrast (with reduced luminance range) desirable in color reproduction.

Future progress in color-television studio operation depends to a large degree on the development of cameras having better resolution, improved stability of transfer characteristic and a greater luminance acceptance range. Improvements in color picture tubes are also needed to realize the full potentiality of the NTSC system of transmission. However, even with present equipment, good results can be obtained through careful attention to details in camera operation and in studio staging and lighting practices.

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Discussion

Stuart M. Cadan (Naval Photographic Center): As in the case of monochrome television, when you increase target voltage you must increase the beam current proportionately to discharge the target. This increases the noise level. What is the effect of this on the color television image?

Mr. O'Brien: One must achieve a compromise adjustment. Because noise is increased, it is common to run beam current at the lowest value which will just discharge highlights. Incidentally, the use of a limited range of luminance values in the stage setting, by holding highlights down, makes it possible to keep beam current low.

An interesting additional point to note is that the noise components from the three camera channels add in quadrature, whereas the luminance portions of the signals are combined linearly providing a gain in effective signal-to-noise ratio. Also, the close-spaced (target to target-screen spacing) type image orthicon used in tri-tube devices has an inherently better signal-to-noise ratio than the tube more commonly used in monochrome cameras.

Color Television Light Sources

By HERMAN M. GURIN

A review of the characteristics and operating features of various light sources for color television is presented. The factors leading to the present choice of tungsten illumination are discussed both on a theoretical and practical basis. Some operating experiences are described and the overall effects demonstrated.

THE ACCELERATED transition to color television from black-and-white has reopened the need for reviewing available light sources which could be applicable to the latest developments. The relationship between the camera and the illuminant is of primary importance, and although the characteristics of the RCA color camera have been more fully described elsewhere,[1] a brief repetition of the essential elements will help in arriving at the best solution.

In the RCA compatible color system, three image-orthicon pickup tubes (#1854) are used. A typical arrangement is shown in Fig. 1. Each pickup tube translates only a portion of the visible spectrum into video information. This is accomplished by the use of the dichroic mirrors and color filters associated with each additive primary channel and result in the taking characteristic as shown in Fig. 2.

The spectral response distribution curves for the three color separation channels are intended for live pickups and correspond to the major positive lobes of the complete spectral response distribution as shown in Fig. 3, which are required to control directly the three reproduction primaries standardized by the National Television System Committee for the reference color receiver given in Table I.

Table I. The Trichromatic Coefficients for the NTSC Reference Receiver Primaries.

Primary	x	y
Blue	0.14	0.08
Green	0.21	0.71
Red	0.67	0.33

In order to keep distortion of the color information to a minimum in the video signals obtained for the three color channels, each tube is operated on a substantially constant gamma curve. This requirement necessitates operating each image orthicon entirely below the knee of its transfer characteristic shown in Fig. 4.

Since we are dealing with a compatible system, it is necessary to provide a contrast range and signal-to-noise ratio which are adequate for both black-and-white and color reproduction of the color signal. It is important therefore to raise the upper limit of the constant gamma region to give the peak highlight signal the highest possible value without extending the operation above the knee of the transfer characteristic. In this manner, there is little, if any, redistribution of secondary electrons over adjacent picture areas and problems encountered in monochrome operations such as "ghosts," "halo," and black edges are avoided. Although contrast in a color picture is primarily achieved by hue rather than brightness information, good contrast is important in the reception of the color on monochrome receivers.

The spectral characteristics of the standard image orthicon are such that no major changes are needed to adapt it for use in color systems. The spectral response of the photo-surface is shown in Fig. 5. The neutral density filters shown earlier in Fig. 1 are used to compensate for the variation in sensitivity of the individual image orthicons by balancing the illumination levels so that all three tubes operate over identical regions of their transfer characteristics. These filters are also required because the normal differences in the light transmission characteristics of the red, green and blue color filters result in

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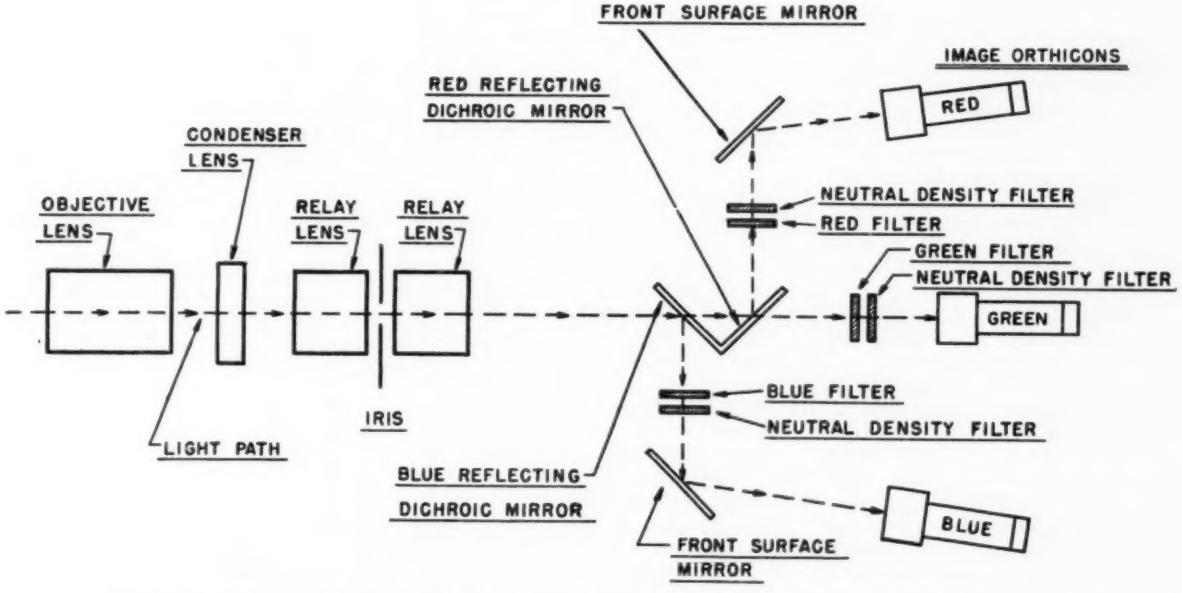

Fig. 1. Block diagram of optical system and general physical relation of components in RCA color camera.

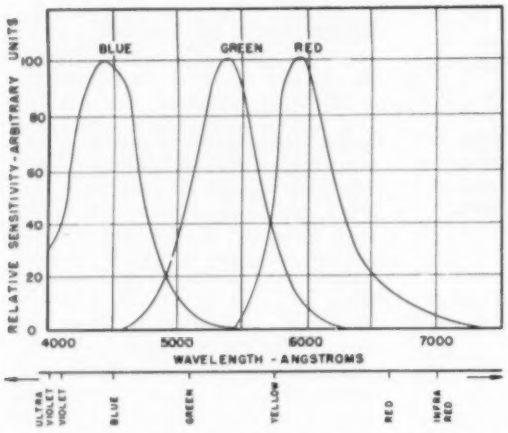

Fig. 2. Spectral response characteristics of the individual color channels of the RCA three-tube image-orthicon color camera.

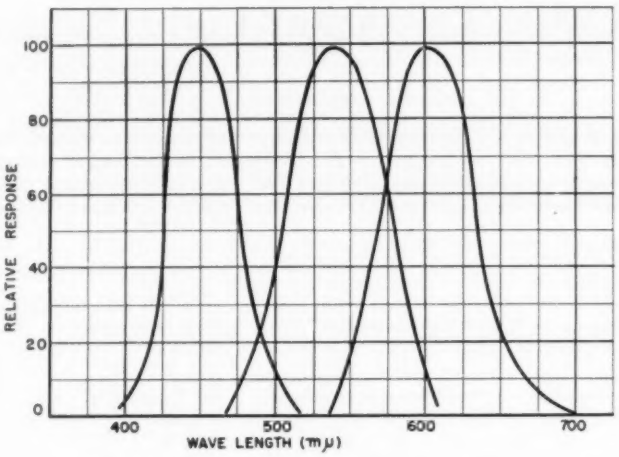

Fig. 3. Ideal spectral response for color camera.

unequal light inputs to the three tubes unless suitable compensation is provided. Since the spectral distribution of various light sources differs widely, different color filters are required for each illuminant as well as a corresponding change in neutral density filters to maintain identical operating points in each of the primary channels.

In judging satisfactory performance, the color reproduction system must be operated such that the chromaticity of colored subject material is reproduced at a fixed chromaticity independent of the spectral distribution of the illumination in the studio. This relationship may be achieved by two methods:

(1) Using an effectively constant subject illuminant for all scenes by employing appropriate energy conversion filters over the light sources or camera objective. The same results (illuminant conversion) may be achieved indirectly by altering the shapes of the spectral response distributions of the camera to compensate for the use of taking illuminants other than that of the standard Illuminant "C," which is taken to have the spectral energy distribution of the ICI (International Commission on Illumination) Standard. Because of filter loss when used over the "taking" light source, the indirect method generally results in a somewhat higher camera sensitivity.

(2) Using effectively constant camera response distributions as previously indicated in Fig. 2, which are modified only in overall gain so that the illuminant or nonselective subjects are reproduced with equal signals for the three channels.

An excellent summary of the properties of common light sources, presented about six years ago by Macbeth and Nickerson,[3] is worthy of review. Since the compatible color system can be adjusted to operate with almost any light source desired, including natural daylight, by the proper combination of filters and dichroics, the advantages for a particular spectral characteristic become secondary.

Another significant conclusion which may be drawn from the theoretical considerations discussed is that light sources of different spectral characteristics cannot be safely intermixed to produce uniformly equivalent color rendition. A number of tests early in the experimental period have borne this out. Results obtained when mixing tungsten at 3400 K and so-called 3500 K white fluorescent lamps (Fig. 6) were unpredictable and particularly unfavorable when a person moved through a set in which the distribution of radiant energy from the separate sources was unequal. The effects were most pronounced when a tungsten spotlight was used to highlight an area already illuminated with fluorescent lamps. Similar experiments using mercury and coated mercury (Fig. 7) mixed with tungsten, proved conclusively that for regular operational needs, such combinations were highly undesirable and were to be avoided.

Fluorescent light by itself theoretically could be employed. It could furnish an excellent diffuse source to keep the brightness contrast range to a minimum and of relatively low radiant heat, but because of its low brightness, the required total illumination on a set demands the use of many lamps so close to the subject material that little physical space is available for scenery, props, curtains and other accoutrement which go to make up a conventional TV scene. In addition, the ability to control the light beam pattern is practically nonexistent and consequently accenting restricted areas within a set particularly on a vertical plane is cumbersome and impractical. Other objections to fluorescent lamps result from the additional accessories required (lamp ballasts), the awkward size and wiring restrictions, especially for long-length instant start lamps and cold cathodes.

Mercury lamps, while extremely efficient in terms of their lumen output, have one serious drawback which eliminates their consideration from present operational use, namely, their inability to reach their full output instantly upon starting or restarting after quenching. When switching from one scene to the next or where a light may be accidentally extinguished, the inability to be relighted instantly is operationally extremely hazardous in obtaining the desired picture.

Bearing in mind the foregoing considerations, it appeared natural to use existing lighting facilities in the first stages of development. Although the incandescent illumination levels are somewhat higher for color than for monochrome, the actual intensity (approximately 350–400 ft-c at $f/4.5$) is well within the tolerable limits. Certainly they are considerably less than those required for most color 35mm motion-picture film.

It is important to note that the area of highest sensitivity in the image orthicon is the blue region of the spectrum. This is a fortunate circumstance because when used in a studio with

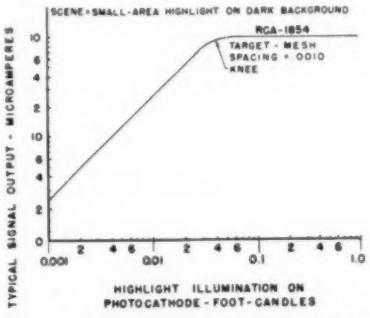
SCENE - SMALL-AREA HIGHLIGHT ON DARK BACKGROUND
RCA-1854
TARGET - MESH SPACING = 0010
KNEE
TYPICAL SIGNAL OUTPUT - MICROAMPERES
HIGHLIGHT ILLUMINATION ON PHOTOCATHODE - FOOT-CANDLES

Fig. 4. Transfer characteristic of the RCA No. 1854 image-orthicon tube.

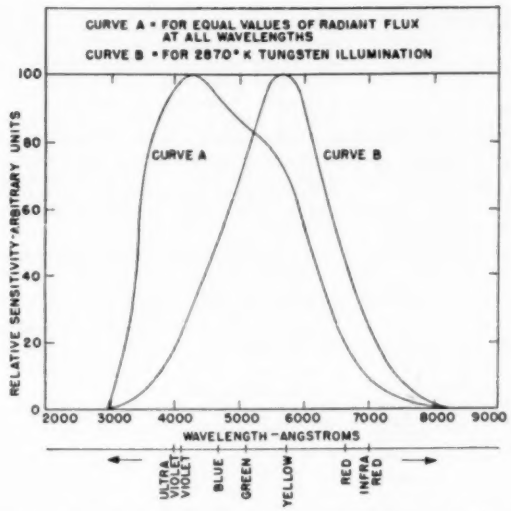

Fig. 5. Spectral sensitivity of the photosurface used in the RCA No. 1854 image orthicon.

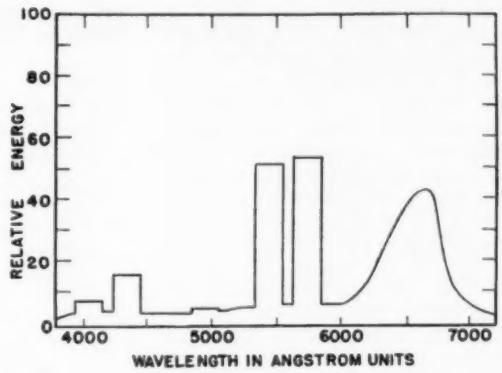

Fig. 7. Spectral distribution of coated mercury lamp. Large irregular area at right represents red light produced by fluorescence of the phosphor coating.

tungsten illumination, the blue and red channels of the studio color camera have nearly equal sensitivities. This is true because the red light emitted by the incandescent source has a very high intensity with respect to the blue component and the blue filters normally used have rather low transmission.

The major reasons for favoring tungsten illumination are based on practical operating requirements. No other illuminant is simpler to install. Wiring, accessories and controls have been developed to a point where a minimum of space, labor and complexity are involved. Because of the widespread use of tungsten and wide variety of fixtures which have been developed, it has been relatively simple to provide the greatest variation in light-beam patterns from sharp spotlights to broad, diffuse lighting.

This diversity of equipment has resulted in greater flexibility and operational economy, a factor which cannot easily be disregarded. At the same time a distinct advantage has been achieved in the selection of tungsten which could be used at relatively low color temperatures (approximately 2700 K to 3000 K) with the attendant long life and low replacement cost both in lamps and manhours.

An interesting and extremely useful condition has been observed in studio operations. Because of the range of wattages of lamps employed — from 1000-w floods to 3000-w, or sometimes 5000-w, fresnel spotlights — a variation in color temperature ranging from 2700 K to 3000 K can be found scattered in a random pattern around a set. The differences between color temperatures are also increased by lamp aging, lenses, reflectors, etc., but fortunately the effects appear to average out so that no serious degradation in color rendition or peculiar effects have been observed due to these variations. The benefits of such latitude to operating conditions are obvious. Figure 8 shows the changes in spectral-energy distribution for the same voltage—but different color temperatures of tungsten.[5]

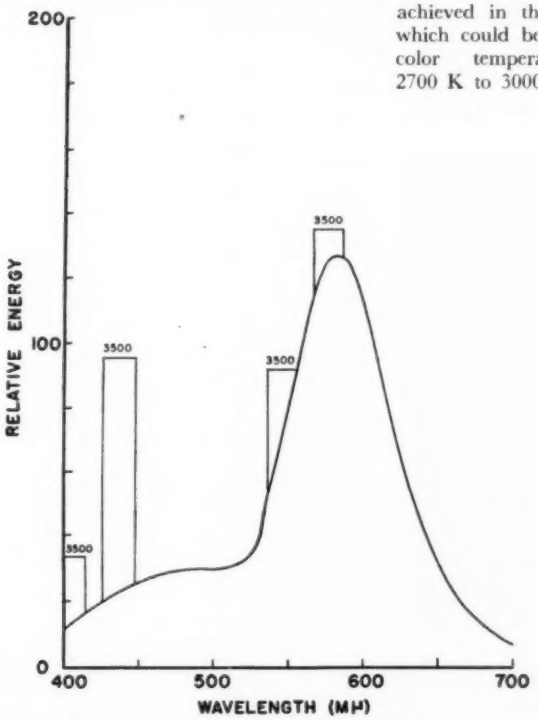

Fig. 6. Spectral distribution curve 3500 K fluorescent lamp.

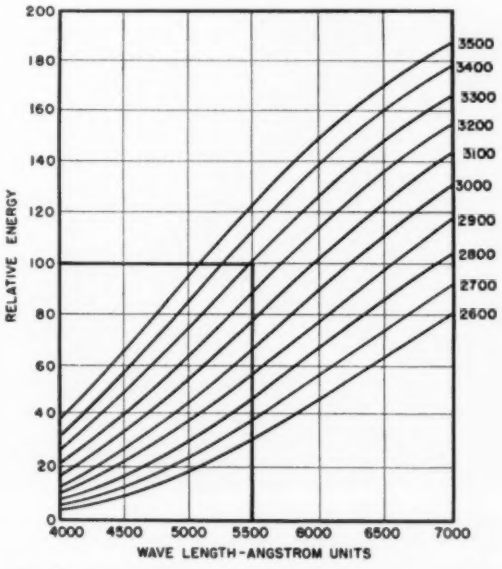

Fig. 8. Spectral energy distribution for tungsten at equal voltages but different color temperatures.

While it is desirable and proper to maintain a uniform color temperature for tungsten sources throughout the studio to obtain consistently satisfactory results, the ability to dim incandescent lights has found special applications. A wide range of spectacular color backdrops can be obtained on a neutral gray background by proportionately dimming each of a cluster of lamps covered with primary additive filters until the desired overall blend is achieved. In combination with beam-pattern control, the special effects obtained are limited only by the imagination and skill of the director.

The mystery of lighting for color television has been greatly overrated. The principal requirements call for a spectrally continuous light source of reasonably uniform quality, satisfactorily distributed to keep the luminance contrast within prescribed limits, and of sufficient quantity to fit the needs of the camera-tube sensitivity in combination with its filters and dichroics. The judgment and skill with which the basic principles are applied, together with the artistic sense of the director, can result in limitless and rewarding opportunities to please the viewing audience.

Special credit is due to O. B. Hanson, Chief Engineer and Vice-President of NBC and G. M. Nixon, Manager of Engineering Development, for their leadership and encouragement, and to the entire staff of RCA and NBC, too numerous to mention individually, for their collective efforts in making possible those prospects which so many have hoped for, for so long.

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2. Norman Macbeth and Dorothy Nickerson, "Spectral characteristics of light sources," *Jour. SMPE, 52:* 157–183, Feb. 1949.
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Discussion

George L. Beers, Session Chairman (Radio Corp. of America): There has been quite a bit of confusion in discussions of lighting in color television due to the fact that the signal specifications are based on Illuminant C. I believe it is correct to state that in terms of the pickup end of the system, Illuminant C is not directly involved. The basic requirement is that regardless of the color temperature of the light source used, the system is set up so that if a nonselective surface — a white surface — is illuminated with the particular illumination used in the studio, the color subcarrier disappears. Then we can operate at whatever color temperature, at the receiving end of the system, we desire; but the signal specifications are such that optimum results are achieved when a color temperature of Illuminant C is employed in the reproducing end of the system. Is that not correct?

Mr. Gurin: That is correct.

Anon: What luminance contrast do you attempt to hold in studio lighting?

Mr. Gurin: The luminance contrast is maintained indirectly by controlling the incident illumination contrast range to no greater than 2 to 1 in most cases.

E. W. D'Arcy: If you could synthesize a light source that would be most suitable for color television, what would it be like in terms of spectral characteristics?

Mr. Gurin: Well, you can balance the system, as it is set up today, for almost any light source you wish to use. As a matter of fact, it's almost a matter of practical requirements rather than anything the system requires. The RCA system will handle almost anything — daylight, mercury, tungsten, anything you wish to use. There is no optimum light source spectrally, if the one used has a continuum. You could use daylight if you wish, so that you can balance for it and come up with the end result which will meet the NTSC requirements. Perhaps the ideal might be expressed as a light source that would provide sufficient illumination with little or no heat, and spectrally continuous.

Richard Blount (General Electric): I think I'd like to object to one statement that you just made. I doubt very much whether you'd like to use mercury. I do not think you will have color reproduction where there is no energy reflected. Isn't that right?

Mr. Gurin: That's correct, but a coated mercury could be used.

Mr. D'Arcy: Is there any edge on daylight as a light source over Mazda?

Mr. Gurin: The advantage of daylight primarily rests on the fact that it's free and plentiful usually. From a spectral point of view, there's no particular preference for it. One of the disadvantages, of course, is the noncontrollable nature of natural daylight with respect to intensity and color temperature and that makes operating a little awkward.

George H. Gill (Kliegl Bros.): What range of color temperature is it possible to operate without having to make camera adjustments? You say that the color television system can operate under almost any type light, but what range is workable without having to stop and make adjustments?

Mr. Gurin: In our operating experience, we have found that we can safely accommodate variations of about 300 K in variation of the tungsten light sources in the studio without rebalancing provided they are randomly distributed and are not discrete changes. In other words, you wouldn't have most of the set illuminated with a number of 3000 K flood lamps and one 5-kw spot of 3400 K. But if the average color temperature is maintained for which the camera was originally balanced the individual variation of 300 K between lamps appears to be handled quite safely.

Underwater Color Cinematography

By DIMITRI REBIKOFF

The major difficulties of subject lighting under water, selective absorption and selective scattering, are overcome by using an equipment with an artificial light source set at the shortest possible distance from the subject. This paper describes such an equipment and discusses the engineering considerations of pressure and corrosion resistance, balancing, hydrostatics, streamlining, etc., that influenced its design. It considers optical problems in connection with absorption and scattering between subject and camera, and special underwater complementary lenses. Both daylight picture taking and artificial lighting are dealt with. The torpedo, its principle, light source, power supply, controls, propulsion and engineering are shown. Experiences and results described are based on 120 dives under water.

Lighting Problems

Daylight penetrates sea water to a very great depth, at least in transparent tropical water such as the Mediterranean. Dr. William Beebe found remaining daylight at 1600 ft. Daylight is sufficient for fairly good lighting and contrast in black-and-white motion pictures even at 200 ft, a depth which is accessible to the modern Aqualung diver. The light intensity at this depth averages 250 ft-c and is sufficient for motion pictures taken at 24 frames/sec with a diaphragm of $f/2$ or even $f/2.8$. Henri Broussard showed that perfect results could be obtained in taking underwater black-and-white pictures at 1/50 sec, or even 1/100 sec, and developing with the new Kodak Microdol Developer. The fact that the sensitivity peak of standard black-and-white emulsion falls in the blue is very fortunate for black-and-white underwater cinematography.

In color, however, it is completely different. At a depth of only 2 to 6 ft, everything is tinged blue-green. At 10 to 15 ft, the selective absorption of sea water is so strong that practically only blue and green are visible, the red and orange having disappeared completely. Satisfactory registration of red or red-containing colors, such as human skin, is possible only within 20 in. from the surface. Furthermore, all the better-lighted shallows are completely covered with green algae. The most interesting subjects, such as fish and coral, are generally fairly deep and inside dark caves where it is impossible to expose even black-and-white film.

Modern color multilayer films feature an intermediate yellow filter layer intended for compensation of the naturally excessive sensitivity of silver emulsions to blue. The result is that the sensitivity of color film is much weaker on the sea bottom than in normal out-of-the-water daylight lighting. Reasonably good pictures cannot be had at more than 3 to 5 ft from the surface without color-correction filters. Of course, filters can be used only where red, orange and yellow have not completely disappeared from the incident light. Very often, however, in depths even from 3 to 6 ft, these colors have disappeared in such a way that any efficient correction filter would completely block all available lighting, and be of no use whatsoever. Besides, the addition of any filter calls for a larger lens opening and decreases the depth of field. It must be remembered that it is difficult to focus under water because the cameraman and the subject are constantly moving, relative to each other. Depths greater than 66 ft are more interesting than the shallower part of the sea bottom where green plants are thriving. Caves too dark for corals are very beautiful in color at any depth. It is thus absolutely necessary to use artificial lighting for successful color motion pictures under water.

As early as 1894, Louis Boutan maintained that underwater artificial lighting was necessary for good underwater photography. In 1899 (in night work at 165 ft) he used underwater arc lamps which would have been excellent light sources for motion pictures. In 1927, an American, Williamson, used artificial light for submarine cinematography, in a filming of Jules Verne's *20,000 Leagues Under the Sea*. His equipment was notably bulky and costly. It resembled a spherical chamber, not unlike a diving bell, with an open bottom to balance pressure, and very large windows. The cameraman with his camera was able to move inside this structure, and even took with him his wife and child. Incandescent lamps were used. One lamp was suspended in a special bulb in front of the window giving a light that was rather similar to sunlight at less than 6 ft. The very large window and the flexible communication tube between chamber and special bulb could not withstand much pressure, so that the maximum depth was about 30 ft.

Commander LePrieur, the great pioneer of Aqualung skin diving, first use a Cine Kodak Special 16mm camera in a watertight case of his own construction. The camera was controlled through pieces of rubber hose. This construction was completely watertight and, in addition, very economical. In 1931, Commander LePrieur made the very first 16mm Kodachrome underwater motion picture with this camera, using daylight. This film interested

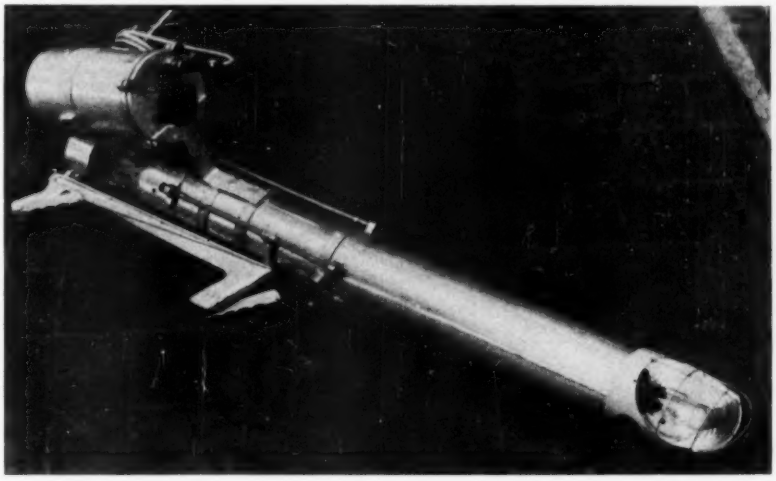

Fig. 1. The motion-picture torpedo. The camera in its watertight case is securely fastened to the torpedo at such an angle that the lamp stays just outside the camera view. At the rear of the torpedo is the propeller and at the front end is the lamp with an anodized reflector.

Presented on Nov. 17, 1953, at the Society's Atlantic Coast Section meeting, by the author, Dimitri Rebikoff, Submarine Research Institute, Cannes, France.
(This paper was first received on April 19, 1954, and on June 22, 1954, as kindly revised by Bernard D. Plakun, General Precision Laboratory, Pleasantville, N.Y.)

Fig. 2. It is possible to separate the camera and the lighting torpedo with a long, watertight cable. This picture was taken at 35 m or 115 ft. The camerman, camera and torpedo are in perfect balance, only the cable being slightly heavy.

many other pioneers in the field of diving.

In 1937, Dr. Hans Hass used a Zeiss Ikon Movikon 16mm camera in a watertight case of his own design during a skin diving expedition in the Caribbean. Although his equipment was incredibly primitive, his film contained many beautiful "firsts" in this field, expecially fascinating shots of tropical fish and dangerous sharks. Hass at that time did not know of the French Aqualung and dove only with a mask and swimming fins, or used an American warm-water helmet with hand pump on the surface. As he worked only in very shallow water around tropical reefs, he had no lighting problem.

In 1945, Captain Jacques-Yves Cousteau, using only daylight, made some beautiful black-and-white show films, some scenes of which were taken at more than 200 ft. Then, in 1948, he used a powerful but cumbersome incandescent lamp under water, very similar to the one used by Williamson. For the first time on Agfacolor, he was able to capture the wonderful red and orange colors of the sea bottom at great depths. The lamp, powered with a cable from the surface, could not match the convenience of the self-contained diving gear. The diver was so hampered with the cable that he found himself in the same situation as the conventional diver with an air hose, and could not move freely in water. A perfectly self-contained light source, independent as the Aqualung itself, would have been an advantage.

In 1951, Captain Cousteau tried magnesium torches that could burn under water. The torches were made in Paris by Ruggieri, a fireworks expert. A gas bubble filled with smoke surrounded the flame, so that the efficiency of the torches was very poor. They were, of course, rather dangerous. Beautiful pictures were obtained, but this light source could not be used for scientific or industrial work. Clearly only an electric underwater lamp could really solve the underwater lighting problem.

Engineering Problems

The camera and lighting system should be built for depths of at least 200 ft, which is easily reached with the modern Aqualung. This means a working pressure of 100 psi, and a test pressure of 200 to 300 psi, for an adequate margin of safety. Rectangular watertight cases with flat sides cannot resist such pressures without becoming too heavy for a self-contained diver, who has to be perfectly balanced in sea water. Plastic cases are especially fragile and cannot be used at a depth greater than 10 to 15 ft. Such cases are suitable only for surface swimmers. A seemingly satisfactory solution is the so-called "breathing" case introduced by Captain Cousteau. This is a rectangular case which need not be strong enough to resist the pressure, as it is used with a small Aqualung made on the same principle as a diver's. The system, however, has proven costly, impractical and unsafe. A faulty exhaust valve caused by corrosion, or mere opening of the valve of the compressed air bottle before diving, can completely destroy the case and camera. The writer prefers the Aquaflex watertight case, which is pressure-resistant even when used without the system. It has the added advantage of the "breathing" system too, thus giving double safety under water.

Exhaustive independent tests made by Fenimore Johnson and ourselves have shown that the self-sealing principle, which is used for boilers and submarine hatches, is very practical and affords absolute safety. In effect, the lid is applied on the case with a force which is proportional to pressure and depth. It is important not to have pressure inside the self-sealing case.

The story of my first dive with a self-sealing case may be of interest in this connection. The case was a modified pressure cooker, the lid being held by a crossbar with a pressure screw. At the end of a 150-ft dive near Cannes, the air in my Aqualung became exhausted before that of my diving teammates. I gave the torpedo with the Verascope Forty Stereoscopic camera to Henri Broussard, showing him where to press to release. Then swimming upwards fast, I had just enough time to see by his actions that he understood me. I was out of the water and resting on the boat deck when I saw, with surprise, a third diver, J. P. Charvos, coming up holding the crossbar. Fortunately, there was no reason to fear a catastrophe. The lid was strongly pressed against the case by water pressure and some minutes later when Broussard came up with the torpedo, we found not one drop of water in the case.

Simple and sturdy, the self-sealing system proved perfectly safe at any depth. This system is the only one used at very great depths and is employed by Beebe's Bathysphere and Piccard's Bathyscaphe. Very accurate machining with a precision lathe is, however, required for any self-sealing case. After many years of research, we designed a standard case made of corrosion-proof anodized aluminum alloy which guarantees perfect protection for expensive cameras and lighting gear. Since most deep-sea dives have to be made out in the open sea under all weather conditions, a watertight case must not only resist pressure, but must also be able to accept shocks against ships' hulls and rocks.

Sea water is one of the most corrosive solutions in nature. It is a direct attacker of metal and also causes galvanic corrosion. Two different metals, one light and one heavy, become a galvanic cell in which the negative electrode or cathode (in our case aluminum) is quickly destroyed by electrolysis. It is therefore necessary to select metals that do not react to cause galvanic corrosion when used together. In the present case it is especially difficult because it is impossible to use copper alloys, nickel alloys and stainless steels as they are too heavy to achieve any balance and, of course, are quite expensive.

Experience has proven that the manufacture of a good watertight case is exceptionally difficult; and especially so if corrosion and pressure-resistance are to be combined with lightness for hydrostatic balance.

Hydrostatic balance under water (which means equality between weight of water displaced by any underwater

assembly and the weight of this same assembly) is very delicate and difficult to achieve. The reason is that an underwater casing made even in an aluminum alloy casting tends to be too heavy. This is a difficult problem, well known in submarine construction, and can be solved only by casting in a cylindrical or spherical shape. In this way, not only is there good pressure resistance, but the external volume can be critically controlled in order to obtain the desired hydrostatic balance of the casing with the camera inside. This balance is so sensitive that the weight of the film reel to be used inside the camera has to be considered.

It may appear that any camera can be used for underwater motion pictures, but actually this is not the case. The size and weight of the camera are important factors in determining the size and weight of the underwater watertight case. Cameras with insufficient motor run have to be avoided, as it is necessary to take long-duration shots while in motion. The surrounding atmosphere is so different and so interesting that the spectator needs some time to understand and appreciate the strange beauty of underwater scenes. Experience shows that the only useful motor in underwater cameras is electric, which facilitates watertight release controls. Tall cameras with one reel upon the other are not practical because they need very bulky and heavy watertight cases. Not only is a big case too heavy to be handled safely outside of the water, but it is often so bulky that it becomes a hindrance to the swimmer while diving.

You have to dive yourself to realize the considerable hydrodynamic drag of water which is about 800 times heavier than air. Even a relatively small case with flat surface (and especially a rectangular one) is an impediment to the underwater cameraman. This is especially inconvenient at greater diving depths because the diver's air consumption becomes very great, and may, in fact, exceed the amount the Aqualung can supply, leading to a very dangerous air shortage. The swimmer, hampered by a bulky watertight case, cannot follow his fellow divers in any exploration where easy and fast swimming is an absolute necessity for safety and efficiency. So hampered, he is unable to follow a fish that a good skin diver, without camera, is able to outswim, nor can he follow interesting species of small fish which swim with quick and unpredictable motions. For all these reasons the diver's speed must be increased by proper streamlining of his equipment.

Streamlining

For the reasons mentioned, we have used lighting units in the form of a torpedo as far back as 1950. This solution has been found most satisfactory and is extensively used in the Submarine Research Institute. For 8mm film, almost any existing small camera can be used, but all available lenses are usually too long in focal length. The wide-angle lens found suitable for this purpose was the Berthiot Hyper-Cinor. For 16mm film, the following types of cameras were found convenient: all cameras using the 50-ft Kodak magazine such as Cine Kodak Magazine; the Bell & Howell Type 200, without turret; and the war surplus Lektro. The biggest drawback of a 50-ft magazine is its very short run. At least a 100-ft roll is necessary. For this purpose, only two cameras were found suitable. The Cine Kodak Special is one, but it has many expensive refinements not needed in an underwater camera, such as the lens turret and direct ground-glass viewer. The new French Beaulieu camera has been found to be very practical and economical. We have replaced the regular spring motor of the Beaulieu with a $\frac{1}{30}$-hp 24-v electric motor which has enabled us to make a perfectly watertight case, without any troublesome winding and release controls. In the fixed-focus system (described in the following paragraphs) and with the fixed-diaphragm made possible by the torpedo, the newest camera case has no mechanical controls whatever. It starts and runs automatically when the torpedo light is switched on, as the motor is simply wired in parallel with the torpedo lamp. With this small and inexpensive camera, we were able in two summers to make more than 120 100-ft reels in as many dives. We never had any trouble during a dive. Its total weight, complete with case, is only 7 lb, its diameter 136 mm and its length only 300 mm.

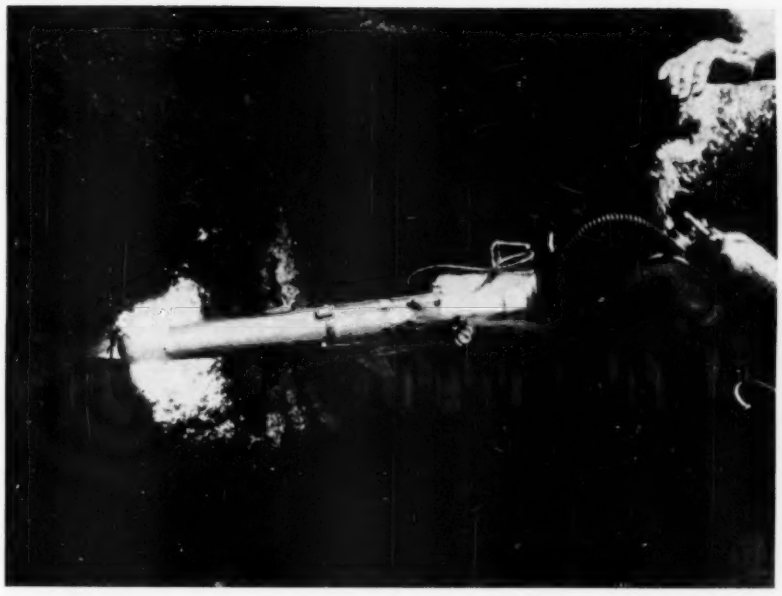

Fig. 3. This picture, from a scene for *Coral Palace*, was taken in a hole where a large octopus was hidden. The small diameter of the torpedo enables the diver to poke the whole assembly into tight spaces which are always teeming with fish. This was taken at a depth of 150 ft, as shown on the depth gauge strapped to the wrist of the diver (in this case, the author). These small spaces or holes reveal remarkable hues of yellow and bright red and are crammed with beautiful fish and other creatures of the sea. For this still picture, the camerman did not use the motor and steadied the torpedo with the left hand.

Special Underwater Optics

Experience has proven it impossible to use normal-focus lenses, especially telephoto lenses, in underwater photography. This is the main reason why a lens turret is not needed. A lens used under water must have the *shortest possible focus* for the three following reasons:

1. *It Is Practically Impossible To Set Range of Lens Under Water.* Even if the camera case is provided with watertight controls, the cameraman as well as the subject are in motion, relative to each other, in three dimensions. It is often impossible even to use a viewer for framing. For this reason, the depth of field must be as great as possible. The only way to achieve a large depth of field is to use the shortest possible focal-length lens. It is not feasible to reduce the diaphragm opening as this would require a more powerful light source.

2. *Field Angle Must Be as Great as Possible.* The cameraman has to work

in a completely different medium. Practice shows that it is absolutely necessary to frame a part of the ocean bottom together with the diver (with the air bubbles above him) in order to explain the real position of the diver to the spectator.

3. *And Yet It Is Necessary to Come as Close as Possible to the Subject.* It is essential to have the smallest possible water thickness between the subject and the camera. Even very transparent water may distort the light to the degree that a difference of 2 ft makes all the difference between a good and a bad underwater picture. Besides this light scattering, light absorption also makes it necessary to come as close as possible to the subject to get a good picture. Usual distances are less than 10 ft for a black-and-white take, and less than 4 to 5 ft for a color take.

Even when using the shortest possible lens focus (18.5 mm for 35mm film; 9.5 or 12.5 mm for 16mm film), we find that it is impossible to achieve sharp images outside the center of the picture when using a flat window. Besides, the flat window makes the focus a third longer, which means 12.5 mm instead of 9.5, 17 mm instead of 12.5, and 25 mm instead of 18.5. This is the reason why it is absolutely impossible to get good pictures with normal lenses such as 25-mm for 16mm film, which then becomes 33 mm owing to water refraction. The only practical way to solve this problem is through the use of an additional correcting lens as computed by professors Ivanoff, Legrand and Cuvier of the French Museum of Natural History, Laboratory of Physics. This corrective lens has proven itself as important as artificial light in getting good underwater or black-and-white and especially color motion pictures. Our first experimental film shown in New York at the joint session of the SMPTE and SPE of November 17, 1953, had been made, for the most part, without this correcting lens and through a flat window. The field was so narrow that very often the divers had hands, feet and even heads cropped off. Even in very clear water, it is *impossible* to get a really good shot farther than 6 to 10 ft from the camera.

Fig. 4. This shot was taken at a depth of 100 ft in and around the ruins of a ship that was sunk during World War II in Golfe-Juan Bay. The author is traveling vertically, coming out of the engine room through an open hatch. He is pulled slowly upward by the torpedo motor, thus avoiding any swaying due to swimming motions.

Daylight

As mentioned at the beginning, daylight can be used only in depths of 3 to 6 ft. Color cinematography by daylight is a matter for surface swimmers without Aqualung. With the proper filters, daylight may be suitable for scenes near the surface of the water — such as spear hunters, shark fighters or conventional swimmers. Without artificial lighting, the eyes and faces of the swimmers wearing masks are not visible. It is only when working with tropical reefs very near the surface that an under water cameraman, such as Dr. Hans Hass, could get any really good results. The North Atlantic and even the Mediterranean are very dull waters near the surface, having no coral reefs. In such places artificial lighting is necessary, but backlighting effects with daylight give the most beautiful underwater effects. At depths of 3 to 6 ft we come into the exclusive domain of artificial lighting.

Artificial Light

For full-color cinematography at any depths, at any time, in any place (especially in the most interesting places such as inside wrecks and caves where fish are to be found), the only possible approach is with artificial light. The old, arc-lamp technique of Louis Boutan, described earlier, would even today be one of the best, except that the watertight lamp cases are quite bulky, and power supply cables from a boat are impractical. Incandescent lamps such as used by Williamson and Captain Cousteau are objectionable for exactly the same reasons. With powerful lamps, there is a large voltage drop which affects the color temperature. Incandescent lamps with maximum color temperatures of 3400 K emit light which is very rich in red and very poor in blue. This is the case, too, with magnesium flashbulbs which have a color temperature of 3800 K. As sea water transmits only blue and green which have very little absorption of great distances, the reach of an incandescent lamp is limited under water. Arc lamps are much better. It is impossible, in practice, to have a full-color reproduction of the sea floor at a greater distance than 3 ft with a 600-w incandescent lamp (which is standard in our smallest motion-picture torpedoes). The diver must have a completely self-contained assembly with powerful lamps and camera.

The first years of our research have led to our electronic photographic torpedo. This is an electronic flash

unit with puncture-proof metallized paper condensers and high-voltage, dry-cell batteries, without vibrator, which allows one flash per second with an output of 200 w-sec. The basic principle is the same as that of the Ikotron electronic flash made by Zeiss Ikon in Germany. The most important characteristic of the photographic torpedo is that both ends are utilized to the best advantage. That is, the lamp and the reflector are at one end, and the camera is fastened at the other, so that the lamp at the front, just outside of the subject frame, is trained on the subject in such a way that the subject is lighted with an angle of 45° between reflector axis and camera optical axis. The camera is mounted at the rear end of the torpedo at a specific angle in order to keep the torpedo out of camera range.

The Motion-Picture Torpedo

Principles: An electronic light source flashing at 16 or 24 times/sec was not pratical, as it would have required expensive and heavy high-voltage batteries and it presented many other technical difficulties. After several years of research we decided on two alternate light sources. For low-powered inexpensive items, we used special 600-w, 24-v incandescent lamps with our special patented watertight case. For maximum output, we used (experimentally) a special xenon arc lamp in a high-pressure quartz tube which worked directly in water, thus providing efficient cooling. This xenon arc lamp is not a flashtube. Its color temperature is about 6000 K. Both types of lamps operated at 24 v. However, the ignition voltage of the special xenon tube is over 25,000 v, which means a most difficult insulation problem. A special anodized aluminum reflector guarantees good distribution of light on the subject. No light may stray back to the lens as it will only be scattered by the water between subject and lens. It is absolutely necessary to have the lamp at the front end of the torpedo in order to have it as near as possible to the subject. It is also essential to have the shortest possible distance between lens and subject.

Power Supply: The power supply is a Yardney high-capacity silver and zinc Silvercel battery. This battery, which is also used for starting jet engines and powering naval-type torpedoes, has two revolutionary characteristics. First, its capacity for a given weight is *six times* the capacity of a good lead battery. Secondly, the voltage does not show any measurable variation during the entire discharge cycle. This means that light intensity, color temperature and camera speed will remain constant during operation. This is one of the reasons why a diaphragm control is not necessary. The diaphragm can be fixed at $f/2.8$ in clear water and $f/2$ in moderately turbid water (with a visibility of more than 10 ft). The high capacity of a Silvercel battery which can be housed in a small torpedo allows 7 min of light with a 600-w lamp. As a 100-ft roll runs through in less than 3 min (at 24 frames), the capacity is quite enough for one reel with plenty of current to spare for propelling the motor. The high initial cost of this battery is more than offset by these two features.

In our medium-size torpedo Type (2), we use a 20 amp-hr Silvercel battery which feeds two 600-w lamps during 13 min. This is enough for at least three reels, which means three dives without recharging. It is necessary to control the discharge of the battery through a built-in watertight voltmeter. Discharge must be stopped below a preset level to avoid reversing some elements.

Controls: The battery is connected to the lamp with a relay operated by a special watertight switch. This system has been proven safe in three years of use It must be completely reliable since a short, under water, can mean the complete destruction of practically everything inside the torpedo. For this reason, brass bars in the best available water-proof insulation are used instead of conventional wiring.

Underwater Propulsion: We have already said that the diver is often hampered by his camera. If an unpropelled equipment is used, the diver is slowed down, even if the assembly is perfectly streamlined. However, the torpedo is electrically driven. The electric motor is $\frac{1}{2}$ hp, and turns a three-bladed propeller, with the result that cameramen can move at more than double the normal speed of a diver without equipment. If the cameraman knows how to swim with the torpedo, he can steer it quite easily under water. This is not

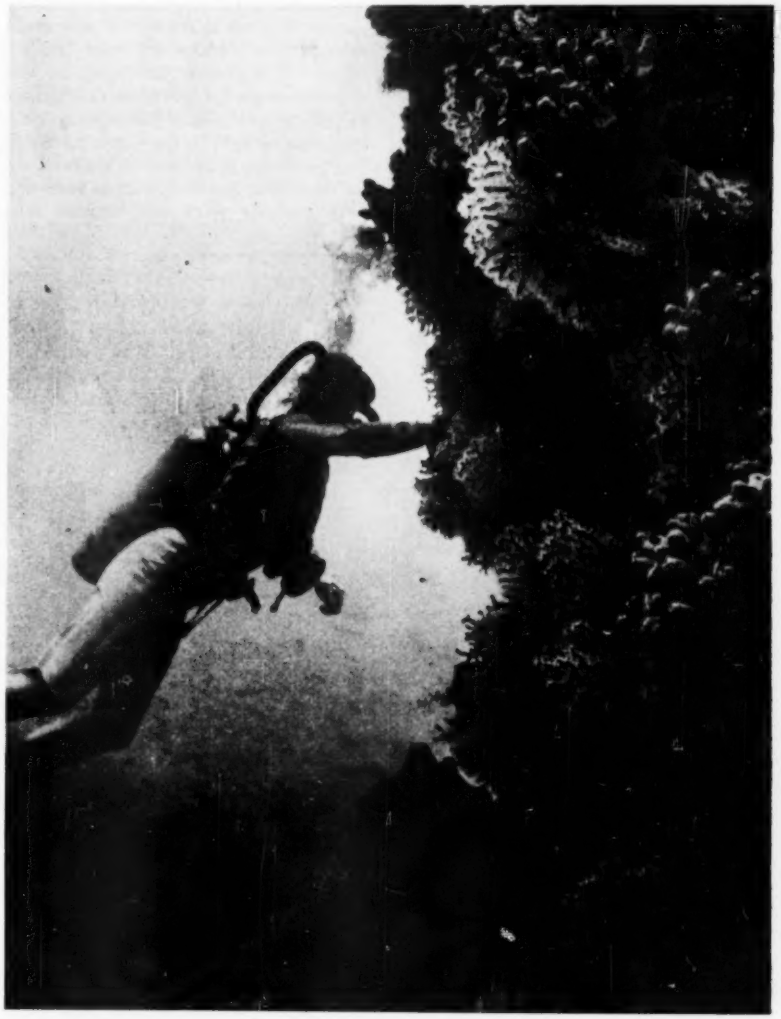

Fig. 5. This scene was taken in Coral Palace at a depth of about 160 ft. This vertical coral wall is blue-black under daylight, but the concentrated light beam brings out the natural gorgeous reds and yellows, only part of which the camera is able to capture.

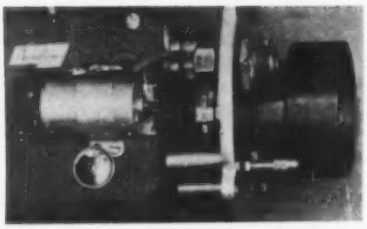

Fig. 6. Camera showing 24-v electric motor, Ivanoff underwater lens and watertight fittings connecting motor to torpedo battery. Constant light intensity makes diaphragm setting unnecessary. Range focusing is not required because the combination of wide-angle lens and underwater correcting lens provides for a depth of focus of from 1 to 20 ft.

only very comfortable, but it enhances safety. To ascend from the greatest depths, it is enough to train the torpedo upwards, that is, in the same direction taken by the air bubbles and simply let the motor go.

Divers who are lucky enough to have a torpedo use it even without the camera. It allows them, for example, to outswim fish or to get to the surface in a very short time — less than 1 min from a 150-ft depth, for instance. The motor, also, is very important in allowing the cameraman to make a new take at an opposite angle to the first one. For this, the cameraman has to swim very fast around his subject and this may be quite dangerous if he is not helped by the powerful electric motor. *The motion picture torpedo has now proven itself, in practice, a wonderful new and indispensable submarine exploration tool which multiplies the action radius of the diver and gives him an exceptional safety margin.*

Engineering

The Rebikoff motion-picture torpedo is designed and computed with the same accuracy as a naval-type submarine. The balance is so perfect under water that its weight is fixed at about 1 oz, so that if you let it go it will sink very slowly to the bottom where it is easier to retrieve than on the wind- and current-tossed surface. Like the camera case, the torpedo is made of hard corrosion-proof anodized aluminum alloy to combine good pressure resistance, the necessary lightness and perfect balance. The test depth is 400 ft which gives working safety to 200 ft, the maximum practical depth to which a self-contained diver can descend. If he lets go of the torpedo at any depth, it simply sinks while remaining horizontal, so that it remains ready for picture taking at any time.

The motion-picture torpedo has a double handle like a submachine gun. The rear grip contains the light and camera switch, and the forward grip contains the motor switch, so that it is possible to use the motor and the light with camera together or independently. Power consumption of the motor is only 450 w, which is less than the 600 to 2400 w taken by the lamp. Thus, there is plenty of current left for the motor after the film is taken. The camera is fastened permanently to the torpedo at the most favorable and previously computed angle, which depends on the type of lens used (especially if it is a flat window or if it is equipped with a special correction lens). The synchronization of the electric camera is made in the simplest way with a watertight cable between torpedo and camera. When the cameraman activates the lamp switch, the camera runs; when the lamp is switched off, the camera stops. The bigger torpedoes are provided with a second pilot light of 50 w which is very practical for preparing a take without excessive current consumption.

First Results

Exactly as with the electronic flash torpedo for still photography, the motion-picture torpedo introduces a new basic principle for underwater color picture taking. The lamps are held at the optimum angle for best results according to the characteristic absorption and scattering of light in the water medium. The powerful lamp and its reflector at the front, and the camera at the rear, are built together with the torpedo into one very sturdy assembly. The very first prototype made according to this principle enabled us to record colors accurately in experimental depths of 150 ft. Despite the fact that we had never made a film before, even as a hobby, we were able to take 35 reels of 16mm Kodachrome in one month without one camera or torpedo breakdown. We had to stop these operations because after years of concentrated research and prototype construction we became physically exhausted by the daily dives of 100 and 200 ft down.

The first unmounted reel won the Scientific Film Award at Cannes in 1952. This feature, only 20 min in length, is now titled *Coral Palace*, enlarged in 35mm Gevacolor and about to be released. It shows, for the first time, the true colors of the sea bottom with their unbelievably bright reds, oranges, yellows and purples. When shooting this film, we discovered that colors become increasingly gorgeous when diving deeper. This applies to dark caves as well. It is difficult to understand this, since the colors that are uncovered by the light beam of the torpedo cannot be seen by normal daylight. The sea bottom under daylight is only dark blue and black, very much like a moonlit landscape. When the diver presses the switch of the torpedo, he discovers (especially if he is at a depth greater than 100 ft) unbelievable scenes in places which, only a moment before, were only dark holes. Perhaps the most beautiful revelation that can be made today is to hold the torpedo at arm's length, poke it as if it were a pistol into a sinister-looking black hole, press the switch and then behold a view that could only happen in a dream. You might see a man-sized grouper eying you with wide-open eyes not moving and surrounded by sparkling jewel corals; bright sponges, lobsters and coral fish, and maybe a timid octopus all lighted up by a man-made sun in indescribable colors.

Fig. 8. Complete camera in watertight case. Note correcting lens (computed by professors Ivanoff, Legrand and Cuvier) for adjusting distortions due to optical properties of sea water.

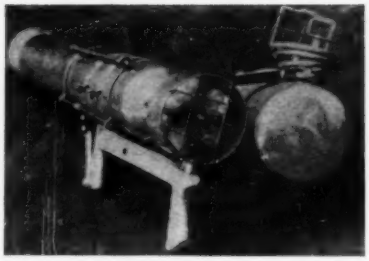

Fig. 7. Torpedo from rear, showing three-bladed propeller. When propeller is not in use, the unit is almost balanced and can be handled easily by the rear pistol grip.

During the summer of 1953 we were able to build two more powerful torpedoes and to make a new short feature, the original take amounting to 85 reels, taken in as many dives all around the Mediterranean, at depths ranging from 50 to 200 ft.

Each new dive is a completely new disclosure of underwater colors and spectacles, and it is just the beginning! We were able in four years of diving to see and register on film a surface amounting to less than one millionth of the Bay of Cannes, the whole Bay of Cannes being only a ridiculously small part of the Mediterranean, the Mediterranean itself being very small indeed compared to the other oceans. Recording on color film the unknown wonders of the deep is a major task. Now, at last, it appears possible for cinematography to prepare or begin the conquest by man of the sea bottom around the world.

Latensification of Multilayer Color Film

By KENNETH M. CAREY

New color films of the negative-positive type have hastened the general trend from black-and-white to color in the motion-picture industry. In order to overcome low emulsion speed of these stocks which limits their use under certain location conditions, an attempt has been made to increase speed. In this paper a method of raising the speed of Eastman Negative Color 5248 from ASA 24 to ASA 80 without objectionable loss of contrast or color shift is described.

One of the continual problems in the documentary cameraman's life is the constant battle for more light for color shooting. With an ASA rating of 16–25 for most commercial color films, a very high level of illumination is required. In the studio this may be of little consequence, but when the location is in some inaccessible place like a coal mine or large factory it is often impossible to secure adequate power to provide sufficient illumination. It is obvious also that the cost of providing the necessary light adds a considerable amount to the production budget.

In recent years the motion-picture industry has accepted the use of latensification of black-and-white films for shooting in large, poorly lighted areas, or where extreme depth of field may be required with low light levels. The process for black-and-white latensification consists of passing the exposed film through a machine on which it receives a further very low level filtered-light exposure of long duration (20 to 30 min). The film is then processed approximately 50% longer than average to produce a negative of normal contrast. Extra development is necessary because, by its very nature, the latensification process affects the densities on the toe of the characteristic curve much more than those on the shoulder. As a result, if the latensified film received normal processing after treatment, the resultant film would have very low contrast. To avoid this, extended development is necessary.

At the time the National Film Board built its latensification unit a few years ago, the suggestion was made that there be developed a similar process for color film. Preliminary tests on reversal color films, then in use, indicated that the maximum effect to be expected was an increase of $\frac{1}{2}$ to $\frac{3}{4}$ stop.

When the demand for color shooting increased using the negative-positive films, this project was revived. After a good deal of careful consideration, it was decided to use three separate filtered-light sources for the "re-exposure." Each filter was selected so that the light passed by it would affect only one layer of the film. The transmission peaks of these filters were chosen to match closely the sensitivity peaks of the color emulsions generally in use.

Working on the basis of trial and error and using hand processing, it was found that color latensification was possible. It was found also that, due to density differences of the filter packs, the output of each light source had to be controlled to provide neutral balance of the finished product. With this information at hand, the black-and-white latensification machine was fitted with three new light sources, each controlled by means of individual variable auto-transformers (Fig. 1). The areas of the filters were cut in such a manner that equal settings on all three lights would produce a reasonably balanced fogging on the exposed negative.

In the initial stages of the investigation some attempt was made to use gamma strips for control purposes. These were latensified and from density measurements attempts were made to adjust lights as required. It was found that this method was not too satisfactory due to a number of variables, some of which are peculiar to our own plant. These were: (1) no reliable color densitometer available; (2) a very unsatisfactory method of making single-layer exposures for sensitometric test strips involving multiple exposure in our 2B sensitometer.

It was decided that for our purposes

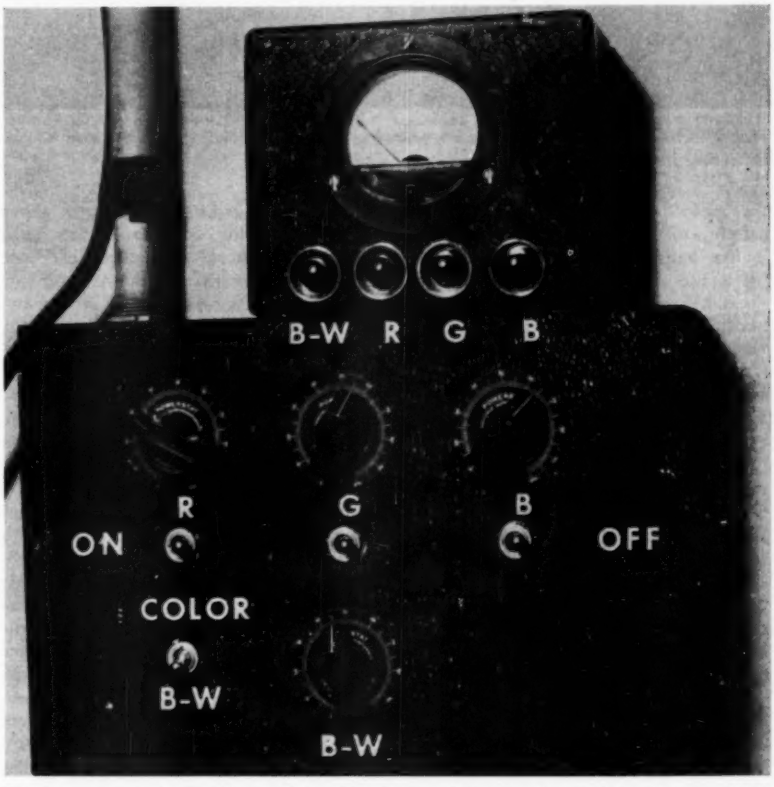

Fig. 1. The control panel for the latensification machine showing: (1) the three variable autotransformers for the red, green and blue lights respectively; (2) the variable autotransformers for the black-and-white light source; and (3) the meter used to check lamp voltages.

Presented on May 4, 1954, at the Society's Convention at Washington, D.C., by Kenneth M. Carey, Technical Research Div., National Film Board, Ottawa, Ont., Canada.
(This paper was first received on March 19, 1954, and in revised form on June 11, 1954.)

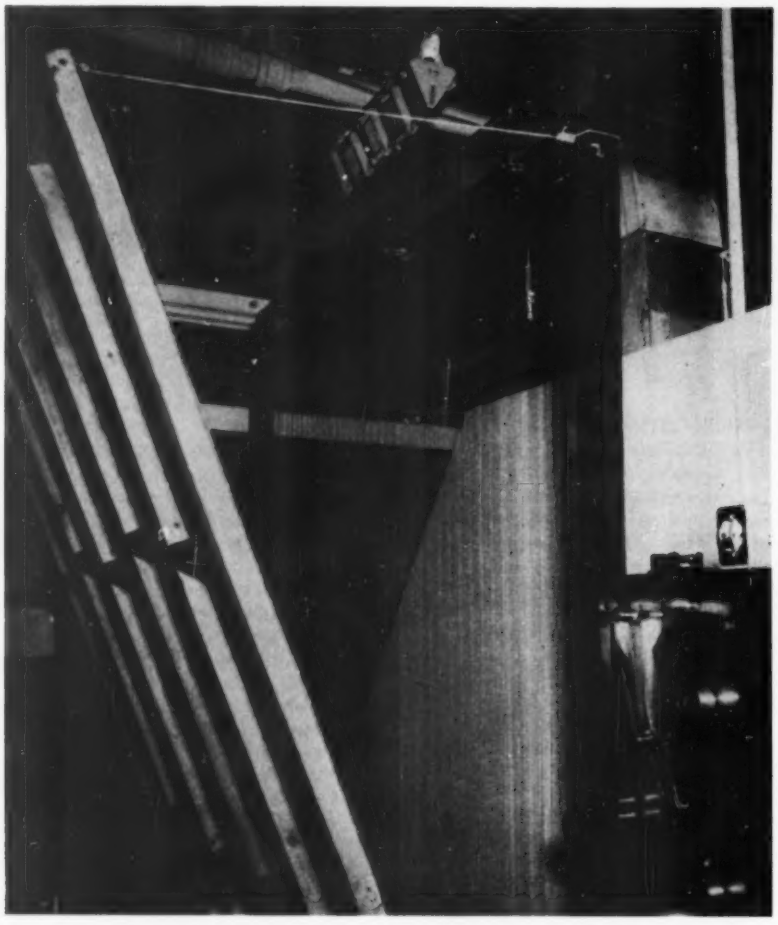

Fig. 2. The latensification machine, showing the position of the lights and of the reflecting boards.

the easiest test would be to shoot a simple scene consisting of gray scale and a color patch. This scene was shot first using the recommended rating of the manufacturer and the negative processed normally. Then an exposure was made, deliberately under-exposing the film by two full stops. This film was put through the latensification process and arbitrarily developed 50% longer than normal. These two negatives were then printed on regular print stock using the filter pack required to obtain the best print from the normal negative. The normal and latensified scenes were then compared in the resultant prints and if a color change was apparent the process was repeated using a slightly different color balance on the latensification machine. This process was repeated until the resultant prints matched visually.

For best results it was found that the base-plus-fog level of the latensified film should be 0.10–0.20 greater than the base-plus-fog level of the normal negative when measured on a standard white-light densitometer (diffuse density). This established the general level of the illumination required. The actual color balance was achieved as stated above by varying the voltages of the lights behind the filters. The details of filters, lights, etc., are given in the Appendix.

When a new batch of film arrives and it has been decided that latensification will be used, a hand test is run immediately. The normal and latensified scenes are compared and, if necessary, the light settings are adjusted. Before any production shooting is done a further test is made and sent to our processing laboratory. Generally there is little difference between a hand processing test and a laboratory test. By this it is not meant that the hand normal negative is the same as the laboratory normal negative, but rather that the difference between the hand normal and the hand latensified test is about the same as the laboratory normal and the laboratory latensified. At the laboratory, the latensified film, clearly marked "For Special Processing," gets 50% longer development than the regular film. These negatives are then spliced together and printed on the same light and the same filter pack. Sometimes the latensified negative must be printed on a higher light because of the slight overall fog but it is preferable to have a slightly heavy negative for close matching.

The finished latensified negative, when correctly processed and exposed, will intercut with regular negative requiring only minor scene-to-scene corrections.

The first actual use of this process at our plant occurred last autumn when it was necessary to shoot sequences of action in a coal mine in color. Here the advantages of color latensification became apparent because: (1) power would be difficult to obtain; (2) transportation of lighting equipment would be expensive; (3) plenty of light would be needed on a very dark subject.

At that time the process was still in the hand testing stage: no screenable footage was available and no batch variations had been attempted. Tests were started immediately on the new batch. Since the first hand test looked promising, a test was made and shipped for processing. When the test returned, the camera crew was already on location. The screening proved that the latensification was successful. There was a slight change in color balance from the normal to the latensified but the variation was readily correctable.

Word was passed along to the cameraman to expose the color film for latensification using the ASA rating of 80, and to make sure that all film so exposed be returned carefully labeled "For Latensification." These were the only instructions he received. Some of the scenes were taken with a 70 ft-c reading. When the unit returned to our laboratory, the latensification process was mentioned to our stills man who said, "So that's what was going on! I was shooting Super XX 1/25 at 3.5 and couldn't see how they could be shooting color."

The process has been used also by our staff for reducing contrast by latensification and then processing normally. Another use would be in background projection sets where at present considerable difficulty is presented by the necessity of obtaining projected images of very high brightness in order to match foreground lighting at low film speeds.

It has been our experience to date that while each batch of film requires minor adjustment to achieve proper balance no large-scale changes are necessary either in level or in balance from batch to batch. This cannot be said to hold, however, for changes from one type of stock to another. Here we have found quite considerable variations to exist. We have found the process causes a slight desaturation of color and a small increase in grain size but these defects are not too serious in comparison to the advantage gained.

The film examples shown at the conclusion of the paper included scenes from

recent films using this process and some experimental work shot during the making of a normal black-and-white picture on an Ottawa location.

The author wishes to express his appreciation to those at the National Film Board who assisted on this project. Special thanks are due to G. G. Graham and C. R. Moxley.

Appendix

Filters used	*Sq. in.*	*Wattage of bulb*	*Footlamberts of bare bulb when voltage set for an average stock*
Blue: Wratten No. 2B + No. 47	1.5	10	350
Green: Wratten No. 61 + No. 16	1.0	10	600
Red: Wratten No. 70	0.6	10	340

The filters were mounted in Kodak "2-way" safelights which in turn were mounted over the longitudinal axis of the machine as shown in Fig. 2. This was done in order that the light would reflect off the panels on either side of the machine onto the film.

The footlambert readings were determined by means of a Spectra Brightness Spot Meter with filter selector at "Open." Exposure time was 20 to 30 min.

Discussion

J. I. Crabtree (*Eastman Kodak Co.*): How do you get uniform travel of the film during an exposure?

Mr. Carey: The machine we've built holds about 500 ft of film. We use the open-rack method similar to that used in a developing machine. In fact, it is one large developing machine rack and the lights are reflected off a pair of panels mounted one on each side of the machine. We feel that the illumination is even enough, because each piece of the film passes through the same path.

Mr. Crabtree: In black-and-white work, have you tried adding hydrazine sulfate to the developer instead of depending on re-exposure?

Mr. Carey: We didn't try that because we at present are using only a single-negative developer, and in that we have to process our negatives for 16, our negatives for 35 and also our master positives and dupe negatives, we cannot use a chemical method.

Mr. Crabtree: Are you using pre- or post-exposure?

Mr. Carey: This is a post-exposure method. We did try pre-exposure but had no success with it.

C. R. Daily (*Paramount Pictures Corp.*): To add a point: The post-exposure method of latensification was perfected for black-and-white film in 1946–1947 at Paramount and was extensively used on many pictures. This method produced a greater speed increase, a better control of the H and D curve and was more practical and reliable than pre-exposure and other methods then known. At that same time, considerable work was also done on the latensification of reversal-type color films and it was found that each color layer could be separately controlled both in speed and curve shape. This control property on color film was used by another organization to treat large quantities of reversal-print film where it was desired to correct one color layer for better printing characteristics. Since Paramount was using the three-strip process at that time for color work, the tests on multilayer film were not put into production use. We are interested to see that the latensification of color films is being rejuvenated since there is a real need for large speed increases on shots such as were shown here, where it may be either too difficult, too expensive, or impossible to obtain adequate illumination for normal-speed film.

Jean St. Thomas (*Photogrammetry, Inc.*): What is the rate of speed of the film at the latensifying light source?

Mr. Carey: Our machine is so arranged that the film is exposed for 20 to 25 min to the three lights and the rate of travel is about 20 fpm.

Mr. St. Thomas: Is there no way of achieving compensation by intensifying the light source and accelerating the film speed at the same time? More feet per minute at a higher level of illumination?

Mr. Carey: No. That is one of the peculiarities of this business. It's similar to the time basis. You can get an increase by using a slightly higher level of illumination and running it through faster, but you get the best effect by using a very low-level light and then running it a little longer.

Dr. Daily: Our experience at Paramount is limited with regard to the influence of the time of post-exposure for the current types of color emulsions. However, in 1946, we fully investigated the effects on black-and-white emulsions for post-exposure times from 1/50 sec to 24 h, using graded intensities of the post-exposure light to produce values from either no added fog to intensities that would add up to 0.20 in fog density. Post-exposure times of 8 to 10 min were found most desirable where the same H and D curve shape was retained as for normal development including the toe, straight line and shoulder portions. With shorter times of post-exposure using higher intensities, less speed increase was obtained accompanied by undesirable curve shapes. With longer post-exposure times, several interesting changes in curve shapes took place with only a slight further increase in speed. It is important to stress the accurate control of all phases of the post-exposure latensification process if reliable results are to be obtained. Lack of such care probably accounted for the process not being adopted after it was first announced by Du Pont in 1938 and 1939. The intensity of the postexposure light source should be controlled with a voltage regulator. Accuracies of plus or minus 0.2 v were found desirable at 60 v. The time of post-exposure is also important, also the time which lapses between the exposure in the camera and the time of post-exposure, also the time between post-exposure and development. With proper precautions taken with regard to each variable, one should get uniform and predictable results.

Mr. Carey: We didn't fully investigate the reversal film, because we were only able to obtain about a half or three-quarters of a stop and the negative-positive films were rapidly coming into use when we started our latensification tests.

W. R. Holm (*E. I. du Pont de Nemours & Co.*): Perhaps I can offer a word about reversal films. The color film to which Dr. Daily referred earlier was a reversal picture called *The Man on the Eiffel Tower*. This was a case where one of the layers was considerably out of balance with the other two and by latensifying this film it was possible to bring the layers all in balance quite well, and so greatly improve the quality. Latensification did work very well in the case of this one layer, and should work equally well for all layers, at least under certain conditions.

High-Repetition Rate Stroboscopic Light Source

By C. C. ROCKWOOD
and W. P. HARVEY

The open time of a Fastax rotating-prism shutter is 40 μsec at 5000 frames/sec. Better action-stopping is achieved with a 1-μsec stroboscopic light. A 5C22 triggered by Fastax sprocket teeth discharges a 12-kv pulse-forming network into an Edgerton lamp 5000 times/sec. An area 3 × 3 ft is adequately illuminated for reflection photography with ASA 100 film at f/2.7.

MOTION-PICTURE photography with the Fastax camera is ordinarily limited to conditions where the image motion during $\frac{1}{3}$ the frame time can be tolerated. At top and bottom of the frame, the effective shutter time is approximately $\frac{1}{7}$, while at the center of the frame the shutter time is more nearly $\frac{1}{3}$ the frame time. An application involving a missile traveling at 400 f/sec was anticipated, and at the highest frame rate available this would cause undue smearing. About 30 frames were desired at intervals of about 200 μsec.

Development of a stroboscopic lamp circuit was undertaken, based on the use of a hydrogen thyratron switch, a pulse-forming network or capacitor and an Edgerton flashtube. The aim was for light flashes of 1-μsec duration, repeated 5000 times/sec. An incidental effect of such a light source would be the elimination of the need for the shutter action of the rotating prism, provided the ambient light level in the region of interest could be kept low enough to avoid fogging.

Figure 1 shows the arrangement of circuits, with some of the waveforms. Synchronizing signals are derived from a variable reluctance pickup mounted in the Fastax, monitoring the passing of each tooth of the sprocket. These synchronizing signals are amplified and used to set off a Schmitt trigger circuit. For frame rates less than 5000/sec, each pulse from the Schmitt circuit triggers a blocking oscillator, and a 6BG6 cathode follower turns on the 5C22 hydrogen thyratron (see Fig. 2). The 5C22 dumps the charge of a pulse-forming network into an Edgerton flashlamp. Ignition of the lamp with little time jitter is secured by adequately overvolting. Recharging of the pulse-forming network is by a resonant choke and diode, and the pulse voltage is nearly twice that of the d-c supply.[1]

For testing the operation of the circuits prior to use with the Fastax camera or for visual stroboscopic observation of repetitive phenomena, a trigger amplifier receives a continuous sinusoidal wave from an external timing oscillator. A multivibrator generates a gate that, on command, allows a given burst of trigger signals to reach the Schmitt circuit. The purpose of this gate circuit is to restrict the maximum number of pulses in a given time, since continuous operation at the maximum repetition rate would cause serious overheating of the flashlamp.

Detailed Circuit Description: The variable reluctance pickup, the external timing oscillator, the gate generator, Schmitt trigger and scale-of-two frequency divider circuits are all conventional and will not be described here. Waveforms in these circuits are shown in Fig. 3.

Power Supply: To relieve the filtering problem, a three-phase full-wave circuit was selected. The requirement of the charging network is 1.3 j/pulse at 5000 pulses/sec, at a level of 12 kv. At the power supply, when resonant charging is used, this becomes 6 kv at 1.1 amp. To achieve adequate filtering from a full-wave supply would require an impractical weight of filter iron and filter capacitors, whereas the ripple factor from the three-phase full-wave supply is only 4.2% with no filter.

When resistor charging is used, the current requirement remains unchanged, but there no longer is doubling of the d-c power-supply voltage by momentary storage in the choke. The full-storage voltage of 12 kv must be maintained by the power supply. To reduce ripple, a 0.25 μf filter capacitor was added, and the 360-cycle component became negligible.

Time Base: Timing marks are placed on the film margin by a pulsed NE-2 not shown in the schematic diagrams. Each mark is about 10-μsec duration, and the repetition rate is selectable, at 500, 1000 and 2000/sec. A 3-mm glass sphere images the annular ring of light from the hot electrode of the NE-2, viewed end-on, onto the film, in the border of the frame, not ordinarily containing subject material of interest. A similar NE-2 and bead lens is contained within the same mounting and is used for recording the occurrence of related events on the same film.

Reduced-Voltage Starting of Fastax Motors: Circuits for starting the Fastax at a reduced voltage, and later increasing to the value corresponding to the desired frame rate, utilize a one-shot multivibrator and a simple RC integrator for measuring time. This integrator is not adjustable, but is designed to provide 70 μsec reduced voltage start, followed by application of the full voltage selected by the Variac.

Impedance Matching: At the outset it was not known whether the flashlamp would break down fast enough to permit the use of a 1-μsec pulse-forming network. Also, the low impedance of the lamp when ignited suggests that to ob-

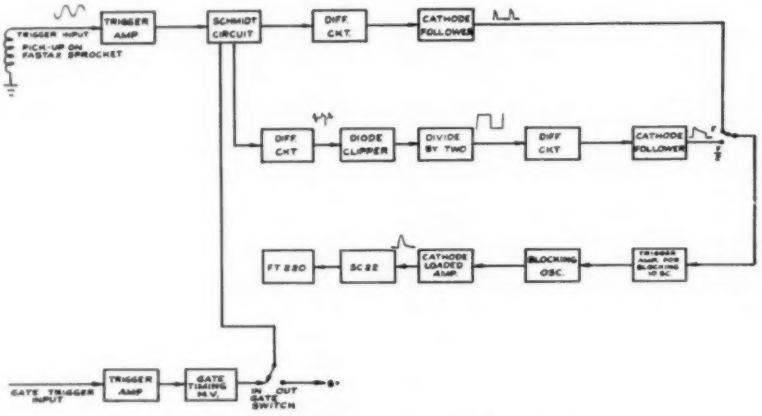

Fig. 1. Block diagram, stroboscopic light circuit.

Presented on May 6, 1954, at the Society's Convention at Washington, D.C., by C. C. Rockwood, who read the paper, and W. P. Harvey, Chicago Midway Laboratories, 6040 S. Greenwood Ave., Chicago 37.
(This paper was received on April 1, 1954.)

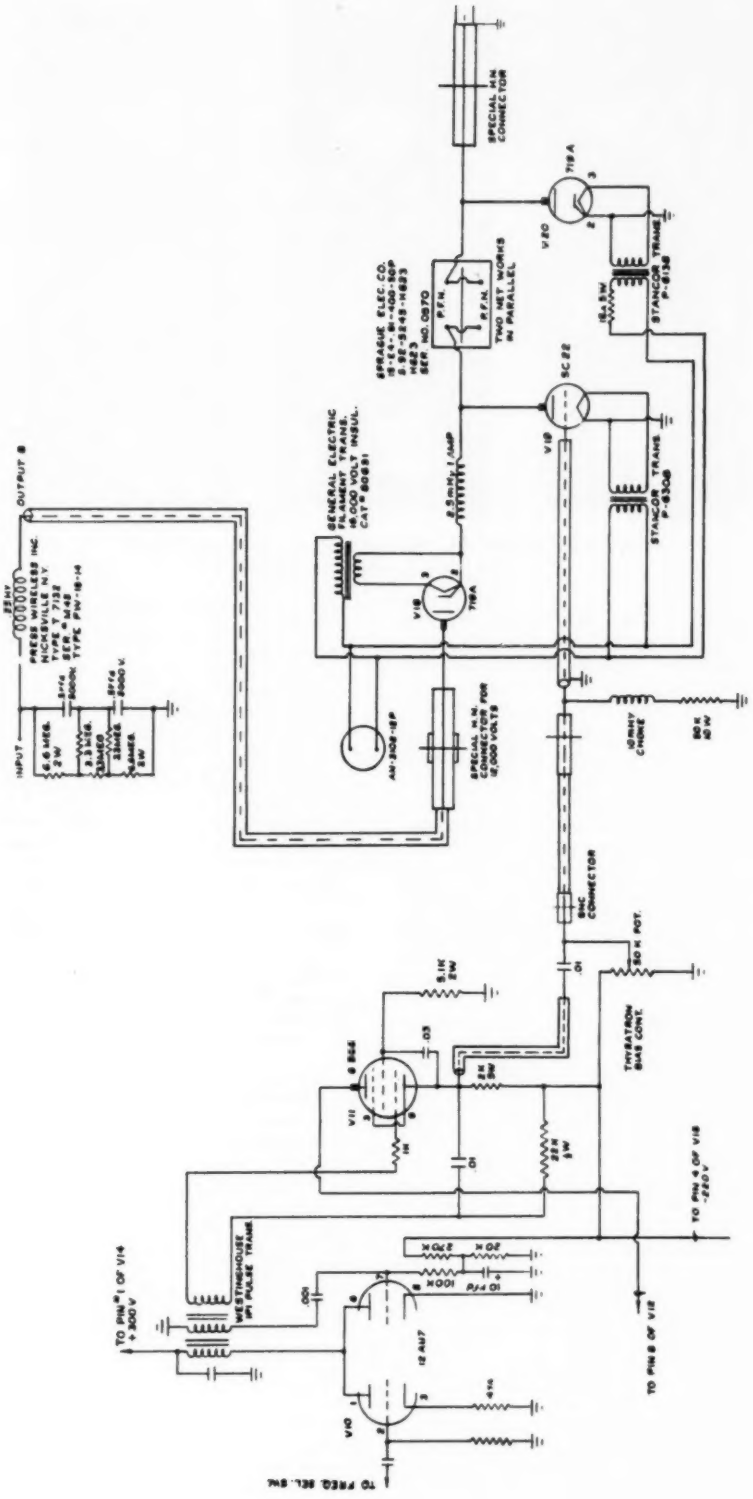

Fig. 2. Schematic diagram, stroboscopic light circuit.

Input waveform to trigger amp (V_1)

Input to clipping diode (V_4)

Output of frequency divider (V_5)

Output of cathode follower (V_6)

Output of cathode follower (V_7)

Fig. 3. Waveforms, stroboscopic light circuit.

tain maximum energy transfer, some impedance matching device might be required, since the impedance of the networks available was 50 ohms. However, the reduced voltage available in the output of a matching transformer was not high enough to secure ignition of the flashlamp. A load impedance less than that of the pulse-forming network helps hold the thyratron plate at a low level immediately after the initial discharge, and thyratron recovery is aided. Hence no matching transformer was used in the final circuit.

Flashlamp: Early experiments with the FT-417 showed that excessively high potentials were necessary to secure fast breakdown. In fact, sparks could be made to leap to the external metal clamps in preference to the helical interior path. Examination of the electrode structure verifies that this tube is particularly unsuited to the type of operation required here, where a sudden application of potential between the main electrodes is expected to break the tube down. Later work using the FT-214 and the FT-220 (same, but with reflector) showed that reliable light flashes would be obtained at pulse voltages of 10 kv. The FT-417 has large, flat electrode surfaces, while the FT-220 has much smaller electrodes, and it is much easier to establish electrostatic fields strong enough to cause ionization. Figure 4 shows the FT-220, the equipment rack and Fastax camera.

Bias and Driver for Hydrogen Thyratron: The recovery of the thyratron is improved by providing a negative bias to the thyratron grid, from a low impedance source of about 200 v. Higher voltages tend to cause continuous ionization. To secure fast ionization of the tube the driving signal should swing the grid to about plus 200 v in less than a microsecond. A blocking oscillator generates the driving signal, and a 6BG6 arranged as a cathode follower transforms the impedance to the low value required in the 5C22 grid.

Maximum Repetition Rate: There is no apparent limitation on repetition rate

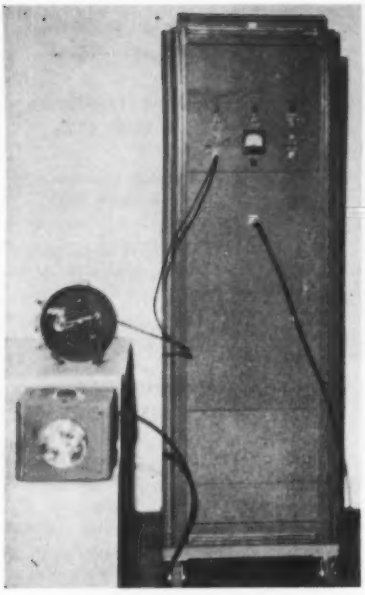

Fig. 4. Equipment rack, flashtube and Fastax camera.

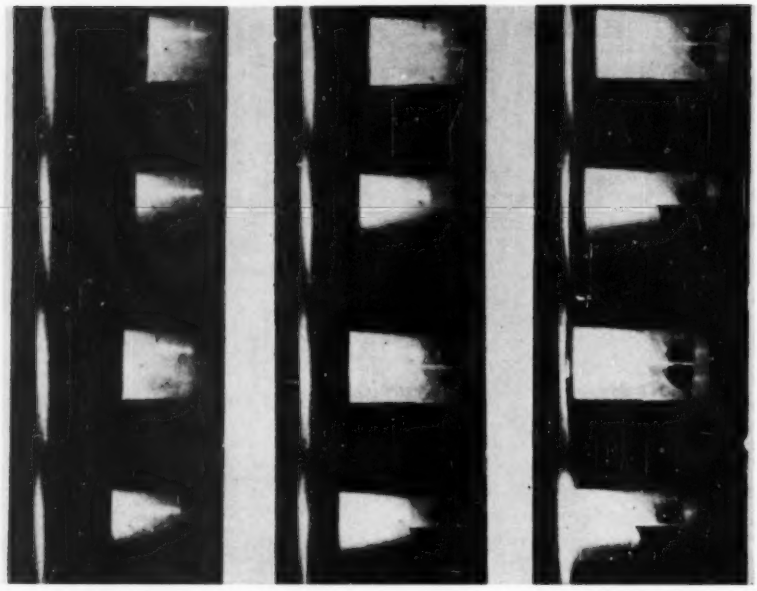

Fig. 5. Motion shot of 400-ft/sec projectile; alternate frames strobe-lighted; frame rate 4000.

due to the flashtube itself, except that due to overheating of the gas-filled helix. Substantially higher repetition rates than those used here are possible, provided that either cooling means are provided or operation is in the form of bursts, with time for cooling allowed. When the number of flashes in a burst is held to a value such that heating is no longer a consideration, the maximum repetition rate will be set by the deionization time of the thyratron. For the loading used here, that is, 1.3 j, the maximum repetition rate is about 10,000/sec. Repetition rates as high as 20,000 are possible, provided the joule loading is reduced in proportion.[1]

Experimental Results: Figure 5 shows 12 consecutive frames of 16 mm film exposed in a Fastax at 4000 frames/sec. There is steady lighting, and on every alternate frame, stroboscopic lighting from the unit herein described. The incandescent lighting was supplied by four General Electric 750-R photospots, about 4 ft above the center of the frame. The stroboscopic light was below at about the same distance from the center interest. It can be seen from the figure that alternate frames show better detail, due to better action stopping of the stroboscopic lamp.

[1] Unpublished Chicago Midway Laboratories report by Y. Kakugawa.

Acknowledgment

Much of the original planning of this lamp circuit was due to F. F. Rieke and J. Burns. The work was performed under Air Force Contract No. AF33-(038)-25913.

Discussion

N. W. Rodelius (Armour Research Foundation, Illinois Institute of Technology, Chicago): Have you gone beyond 5000 frames/sec?

Mr. Rockwood: Not with this loading. To go to higher frame rates one must use a smaller energy content per pulse.

Harry L. Parker (American Speedlight Corp.): In regard to this matter of loading, what is your duration of burst?

Mr. Rockwood: We run 100 ft of film in the Fastax, about 5 sec.

Ed Noel (General Electric Co.): The FT-220 has a very broad coverage and optically it's not very efficient for many of the research applications. In many cases where you do not want the very broad beam that the FT-220 gives, you can use a separate reflector of proper contour with the FT-210 or FT-214 and either very greatly reduce your electrical input or, with the same electrical input, increase your photographic effectiveness.

Mr. Rockwood; With the FT-220 with its beam or cone of 45°, we had just enough light for our 3-ft coverage. It was just a fortunate circumstance.

W. O. Johnson (E. I. du Pont de Nemours & Co.): Do you get that for background lighting, that is, shadowgraph-type lighting or direct frontal illumination?

Mr. Rockwood: This is reflection photography, yes.

A. Earl Quinn (Eastman Kodak Co.): Could you tell us the duration for a frame of this flash?

Mr. Rockwood: The pulse-forming network is a 1-μsec network. The light is not more than 1-μsec in duration.

News and Reports

SMPTE 76th Convention October 18–22 — Los Angeles

The announcement of the general program and sessions will be sent to members in the latter half of August, about a week after this *Journal* is mailed.

Any information about a subject or paper which should be on the program should be telephoned at once to Program Chairman Ralph E. Lovell, National Broadcasting Co., Hollywood. Color — in television, cinematography and exhibition — is the special theme of this convention.

Plans for equipment exhibits are in the hands of Thomas J. Gibbons, 446 North La Brea Ave., Hollywood 36.

The Ambassador is the headquarters hotel. Reservations may be made by direct communication to: Ambassador Hotel, 3400 Wilshire Blvd., Los Angeles 5 (mention the Society and the 76th Convention). Also reservations may be made by writing, wiring or calling:

In New York, 455 Park Ave., MUrray Hill 8-0110

In Chicago, 333 N. Michigan Ave., ANdover 3-6222

In San Francisco, 210 Post St., GArfield 1-6217

In Dallas, 3906 Lemmon Ave., LOgan 5050

In Washington, D.C., Leonard Hicks, Jr., The Barr Bldg., EXecutive 3-6481

In Toronto, 392 Bay St.

The Ambassador's rate schedule per day, all rooms with bath, is:

Main Building

Single room, $9.00, 11.00, 13.00, 15.00, 17.00.

Double room (twin beds), $12.00, 14.00, 16.00, 18.00, 20.00.

Two rooms, bath between (three persons), $17.00, 19.00, 21.00, 27.00.

Parlor, Bedroom (one person), $25.00, 27.00, 31.00, 33.00.

Parlor, Bedroom (two persons), $28.00, 30.00, 34.00, 36.00.

Garden Studios

Room (one person), $15.00, 17.00, 19.00, 21.00.

Room, twin beds (two persons), $18.00, 20.00, 22.00, 24.00.

Room, private sun deck or terrace (one person), $19.00, 23.00; (occupied by two persons), $22.00, $26.00.

Large living room, large bedroom (one person), $35.00; with private sun deck, $45.00.

Large living room, large bedroom (two persons), $38.00; with private sun deck $48.00.

Section Meetings

The Pacific Coast Section's regular monthly meeting was held on June 17th in the El Capitan Theatre, Hollywood. Including the members of the American Society of Cinematographers who were invited in a body and other guests, the total attendance was 625 which is a record for a Pacific Coast Section meeting.

The program was a symposium broadly covering the problems connected with motion-picture films for television. The meeting opened with a delayed telecast of the Dinah Shore show and the Camel Caravan newsreel. Jack Webb then discussed the production of the Dragnet show and the show's director of photography, Edward Coleman, described the photographing of this very popular show.

Next, three Hollywood members of the American Society of Cinematographers discussed the photographing and lighting of the television films which they photograph. In each case, selections from the shows were displayed: Norwood Brodeen for the Loretta Young show; Hal Mohr, the Joan Davis show; and Walter Strenge, Waterfront and My Little Marjie.

Cameron Pierce of ABC-TV then delivered a very informative paper on the problems of projecting and transmitting television films. The paper was illustrated with slides showing the effect of lighting, picture composition and contrast, processing and other factors on the quality of the received picture.

The meeting was then opened for questions from the audience with the above speakers and the following persons associated with television films forming the panel of experts: Oscar Wick of NBC; Gil Wyland of CBS; Sid Solow, Consolidated Film Industries; Harlan Baumbach, General Film Laboratories; and Allan Haines, Pathe Laboratories of California.

Jack DuVall, Program Chairman of the Pacific Coast Section, is to be congratulated for his courage in attacking such an extensive subject on one evening, and for his excellent job of organizing and carrying out the program. A special vote of appreciation is extended by the Section to Ralph Lovell, member of our Pacific Coast Board of Managers and supervisor of Kinescope Recording at NBC, Hollywood, for his very significant contribution to the interest and showmanship of the program. Ralph organized and directed the use of NBC's 35mm film projection, direct-viewing television monitor and large screen projection providing facilities for the various demonstration material shown throughout the program. The selections from television film programs were simultaneously displayed on all three media. Still slides relating to displays were shown on both types of monitor systems.

The Society also wishes to thank Mr. Tom Sarnoff of NBC for the hospitality extended to the Society in placing the El Capitan Theatre and the NBC-TV viewing facilities at our disposal for the program.—*E. W. Templin*, Secretary-Treasurer, Pacific Coast Section, c/o Westrex Corp., 6601 Romaine St., Hollywood 38.

The Atlantic Coast Section Board of Managers held their regular monthly meeting at the Eastman Kodak offices, 342 Madison Ave., New York, on June 3. Everett Miller reported to the Board on the meeting of the Board of Governors held during the Washington Convention. Among pertinent topics reported and discussed were proposals for an administrative code for Boards of Managers of local sections.

The main business of the meeting concerned the nominations for officers and board members for the next calendar year. A nominating committee was appointed to consist of the following members: Everett Miller, J. Paul Weiss, George Lewin, Frank E. Cahill, Jr., William G. Offenhauser, Robert E. Shelby and William B. Lodge.

At the program meeting of the Section held in the evening following the Board of Managers Meeting, there were present 41 members and 6 guests. A paper on "Improved Techniques for Television Recording With Ultraviolet Photography" by John Brumbaugh and R. O. Drew, both of RCA, Camden, was presented by Mr. Drew. A tabulation was also made of comments concerning items of interest for the programs. Heading this list was Television Recording, followed by Sound Recording, Cinematography and Color Films.—*C. W. Seager*, Manager, Atlantic Coast Section, c/o Ansco, 405 Lexington Ave., New York 17.

Review of Proceedings of the Department of Defense Symposium on Magnetic Recording

On October 12-13, 1953, in Washington, D.C., a Symposium on Magnetic Recording was held under the auspices of the Department of Defense. The purpose was to provide a common meeting ground for technical personnel of both industry and the Department of Defense for presentation of papers and discussion on the general subject of research and development in the field of magnetic recording. While the emphasis was always upon military needs, most of the subjects discussed were also of interest to manufacturers and users of recording equipment and media in motion picture and television fields.

The Proceedings of this symposium have been released in a mimeographed report, dated March 1, 1954, by the Department of the Navy, Bureau of Ships, which was responsible for the organization of the meetings.

Two of the papers presented were sponsored by the SMPTE. These were papers #7 and #12 in the complete list given below. Dr. Frayne's paper reviewed much material which has already been published in the *Journal*, but also added some discussion of magnetic striping and electrical printing of multi-magnetic tracks for cinemascope release prints. Mr. D'Arcy's paper presented the various recording and reproducing characteristics which have been proposed and discussed at various meetings of the SMPTE Subcommittee on a Standard Reproduce Characteristic for 16 mm Magnetic Projectors.

Paper #1 by Youngquist and Wetzel of Minnesota Mining & Manufacturing Co. on "Ferrite-core magnetic heads" is substantially the same paper presented previously at the 74th Convention of the SMPTE. It should be of particular interest

at this time since its publication in the SMPTE *Journal* has been temporarily withheld, pending completion of the research work.

Papers #2 and #3 deal with a special Electron Beam Magnetic Reproducing Head which eliminates the low-frequency loss inherently present in conventional magnetic heads, and which makes it possible to reproduce low frequencies down to d-c without equalization.

Papers #4 and #5 deal with a magnetostatic reproducing head which at present is of interest principally for instrumentation work.

Paper #6 describes research work on the development of transistor amplifier circuits for use in playback equipment.

Paper #8 deals with every detail of the design of the tape transport system, from the feed reel to the fully wound take-up reel, including flutter, head contact, and fast forward and re-wind problems.

Paper #9 discusses the factors involved in recording machine performance with respect to flutter, constancy, and amplitude uniformity, as dictated by tape coatings, backings and reel design.

Papers #10 and #11 are of special interest to the field of data recording.

Papers #12 through #18 inclusive, all deal in detail with the general problems of standardization of frequency characteristics, methods of producing standard reference tapes, and using such tapes in the evaluation of commercial tapes and recorders.

Following is a Table of Contents of the Proceedings:

#1. "Ferrite-core heads for magnetic recording" by R. J. Youngquist and W. W. Wetzel

#2. "A vacuum tube for an electron-beam magnetic reproducing head" by L. E. Loveridge

#3. "Core structures for the electron-beam magnetic reproducing head" by J. W. Gratian

#4. "A magnetostatic reading head" by S. M. Rubens and A. B. Bergh

#5. "Performance characteristics of magnetostatic reproducing equipment" by W. R. Boenning

#6 "Playback of magnetic recordings through transistor amplifiers" by C. E. Williams

#7. "Components and mechanical considerations for magnetic sound on 35mm film" by John G. Frayne

#8. "Basic mechanical considerations for tape transport systems" by O. C. Bixler

#9. "Mechanical factors governing tape coatings, backings, and reel design" by J. E. Johnston

#10. "Magnetic recorders for data recording under adverse environments" by G. L. Davies

#11. "Improved performance of magnetic recording system for precision data" by Walter T. Selsted

#12. "Present status of a 16mm standardized reproduction characteristic" by E. W. D'Arcy

#13. "Magnetic tape testing on a comparison basis" by Walter H. Erikson

#14. "Characteristics of recent commercial ¼-inch magnetic tapes — effects of trends on Navy tape standardization" by F. Comerci, S. Wilpon and R. Schwartz

#15. "Some notes on problems encountered in the use of the standard reference tape" by Frank Radocy

#16. "A standard magnetic tape recording for standardizing the characteristics of Navy recorder-reproducers" by F. Comerci, S. Wilpon and R. Schwartz

#17. "Equalization of magnetic tape recorders and general recorder performance tests" by Frank G. Lennert

#18. "Methods of measuring surface induction of magnetic tape" by J. D. Bick

Copies of the Proceedings are being made available to Government and industry groups who are actively engaged in research and development, manufacturing, or direct application of magnetic recording techniques to Department of Defense problems and applications.

Inquiries for copies, with some information on the "need to know" should be directed to: ASTIA Document Service Center, Knott Bldg., Dayton 2, Ohio.— *George Lewin.*

Biographical Note

John George Capstaff has retired after more than 40 years of service in the Kodak Research Laboratories. Mr. Capstaff, head of the Special Photographic Department of the Laboratories, is an outstanding pioneer in photography, a noted inventor, an able experimenter, a meticulous instructor of neophyte photographers, and a well-known technical counselor to the motion-picture industry. He has received numerous awards in recognition of his many outstanding contributions to photographic technology and practice.

In a manner of speaking, Mr. Capstaff joined the Kodak Research Laboratories before they were organized. As a young man in England and in his spare time from his portrait studio, he experimented with photography, inventing several modifications of the photographic process. In 1912, learning from friends that Dr. C. E. K. Mees had been asked by Mr. George Eastman to organize a research laboratory for the Eastman Kodak Co., Mr. Capstaff applied for a position. He was engaged by Dr. Mees to work at Wratten and Wainwright to learn the technique of making color filters to prepare him to come to Rochester to take charge of the production of filters and the experimental work related to them.

Mr. Capstaff had not been long in Rochester before he began experimental work in several fields of photography. By 1914 he was working on processes of color photography, and a two-color portrait process was worked out by him and exhibited at the World's Fair in San Francisco in 1915. It was called the Kodachrome process but is related in name only to the Kodachrome process and materials currently in use. The process was also adapted to motion-picture photography by printing the two color images in register onto opposite sides of double-coated film by means of an optical printer.

Mr. Capstaff's outstanding contribution to photography is his invention of a practical method of making motion pictures for home use. Before 1914, much work had been done in this field by others and while the design of apparatus had progressed satisfactorily, the usual method in photography of making prints from negatives was, for the amateur motion-picture enthusiast, both expensive and complex. In 1914, Mr. Capstaff applied the reversal process to amateur motion pictures and became convinced that this method would be successful commercially where other methods had failed. He felt that the reversal process, which eliminates the need of additional film for the positive print and the printing operation, would reduce greatly the excessive cost of pictures for the motion-picture amateur. Then by making easy-to-use, low-cost equipment, a method would be available to do for the potential motion-picture amateur what roll film and the snapshot camera had done for the amateur still photographer.

The reversal process paved the way for inexpensive home movies, but with the film available at that time provided only limited camera exposure latitude, and the quality of the pictures was adversely affected by the unevenness in the emulsion coating. These difficulties were overcome by Mr. Capstaff by the use of a controlled second exposure which partly compensated for the effects produced by variations in emulsion thickness and, by partially correcting for improper camera exposures, effectively increased the exposure latitude. This improved reversal process gave much better results than could be obtained without the control of the second exposure and led to commercial success. The process was announced in January 1923, and the film and apparatus were introduced in June of that same year.

Mr. Capstaff continued his experiments, and many improvements in the equipment used for exposing, processing, and projecting the film were devised by him. In 1932, "Cine 8" film and apparatus were introduced, the film being processed in the same manner as the 16mm film.

In 1925, he began work on a three-color additive process of color photography which had been developed in principle by French inventors, the rights having been secured by the Eastman Kodak Co. in that year for application in the 16mm Cine Kodak program. This process, in which lenticulated film is used, the lenticules forming images of filters fitted in the lens, was introduced commercially in 1928. Research work on a 35mm lenticular process was carried on

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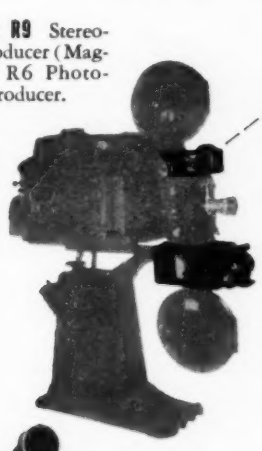

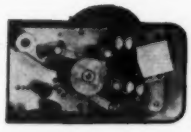

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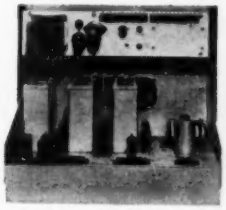

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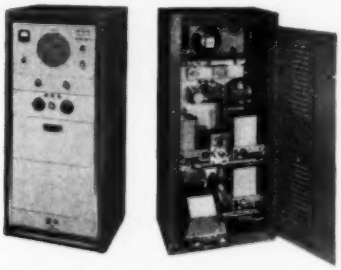

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subsequently in collaboration with motion-picture production companies.

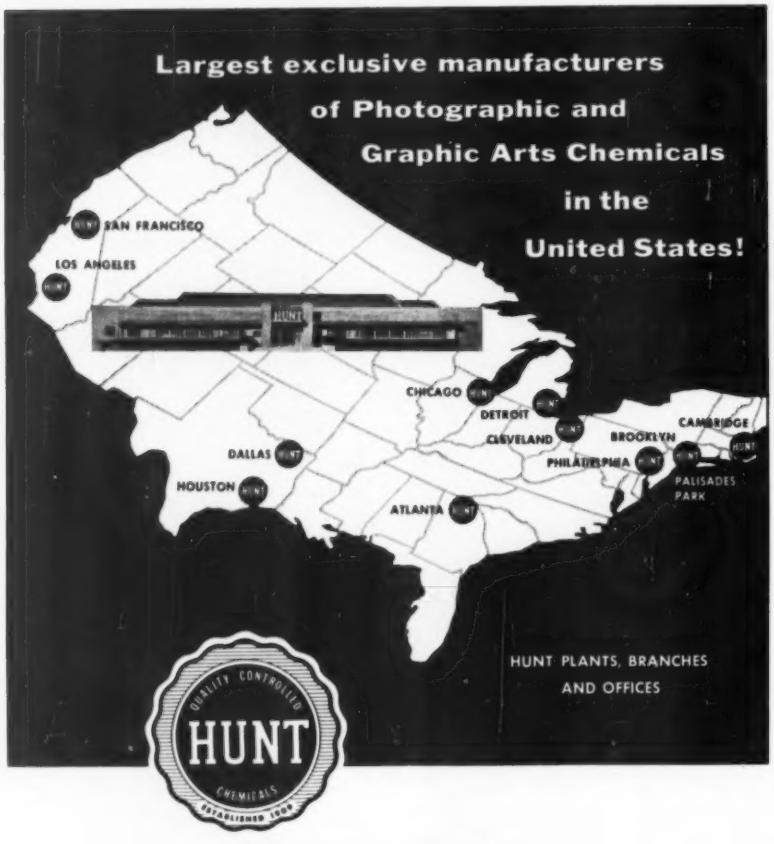
During Mr. Capstaff's early work on the Kodachrome process he discovered that the addition of a yellow dye to the emulsion provided a useful method of controlling the depth of the exposure and also had the effect of increasing the resolving power of the emulsion, thus greatly extending the latitude and lowering the maximum contrast. From this and other innovations, he devised special films which have contributed greatly to the technical excellence of modern motion pictures in black-and-white and in color, notably films for the production of duplicate negatives.

In 1927, he established the formula of a developer especially suitable for the production of fine-grained images on negative film. This formula, D-76, met with ready acceptance and is used very widely by amateur and professional photographers for all classes of work.

No account of Mr. Capstaff's work would be complete without some mention of the training which he has given through the years to his associates and assistants. Many men in the organization of the Eastman Kodak Co. are proud to acknowledge with gratitude their obligation to him. This feeling is also shared by many motion-picture engineers throughout the industry, many of whom have been helped by his wide knowledge and ready invention.

For his key inventions which are the basis of amateur movies, Mr. Capstaff received the Modern Pioneers Award of the National Association of Manufacturers in 1940. He was awarded an honorary fellowship in the Royal Photographic Society in 1944 and received its Progress Medal in 1946. In 1950, the Photographic Society of America awarded him an honorary fellowship. The design of a processing machine incorporating several new principles brought him an honorary mention from the Academy of Motion Picture Arts and Sciences in 1943. The Society of Motion Picture and Television Engineers awarded him its Progress Medal in 1944.

Mr. Capstaff has published a number of papers on his work in photography (most recently, "An experimental 35mm multilayer stripping negative film," in the April 1950 *Journal*) and has been granted over 75 patents. His work has been fruitful, and the high technical excellence of motion pictures today owes much to his pioneering efforts.—*R. G. Tarkington.*



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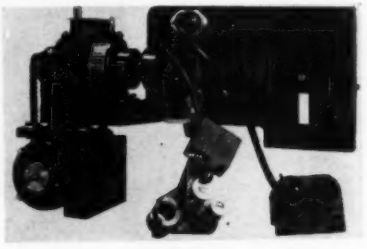
Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.



An automatic fade attachment for use with Models D and J Bell & Howell Continuous Contact Printers is being made by the Motion Picture Printing Equipment Co., Skokie, Ill. In the fade attachment, the shutter blades are driven by a mechanical clutch which is connected to a variable-speed transmission whereby the fade lengths can be varied. Fades of from 10 to 100 frames can be obtained. The mechanical clutch is operated with a breaker box, which operates from a standard film notch placed in the negative on the soundtrack side of the negative. The attachment is provided with an indicator light unit which indicates when the shutter blades are opened and when closed. Two 4-w, 120-v lamps are mounted in this housing and are operated by a microswitch inside the fade attachment. For Model J the attachment costs $695.00 f.o.b. the plant; and for Model D, $745.00.

A slide rule calculator for estimating the relationship between running time, footage and cost of 16mm and 35mm films will be sent by Sidney P. Solow, Resident Manager, Consolidated Film Industries, 959 Seward St., Hollywood 38, to any Society member who sends him a self-addressed 9-in. envelope bearing 6¢ postage. Given the unit price per foot of film and either the running time in minutes or the footage, the total cost and either the footage or the running time are shown.

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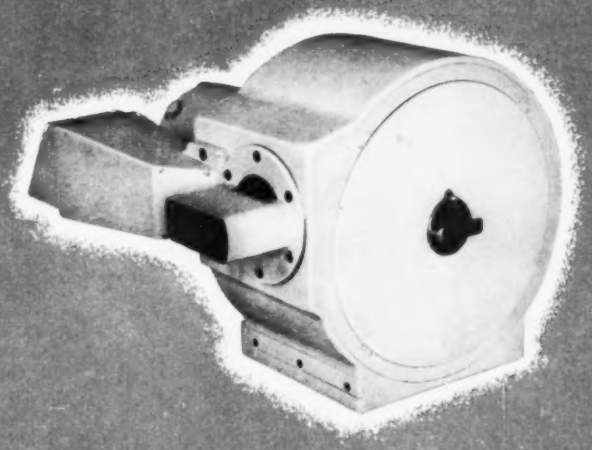
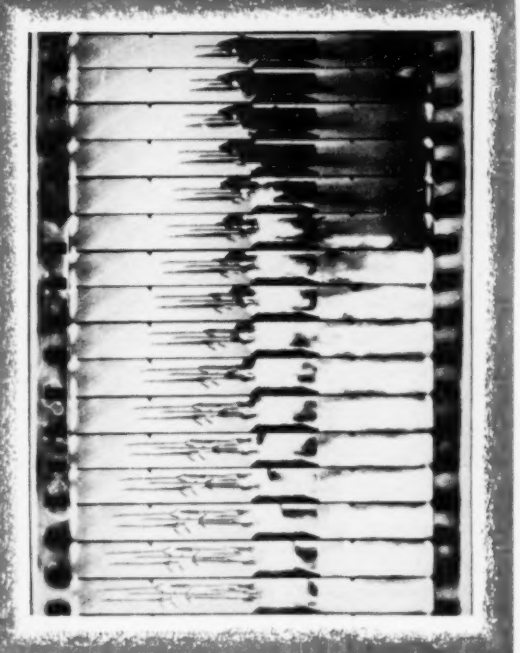




Rocket firing photographed by 70MM-1A Camera
Official Photograph U.S. Navy

70MM-1A
400 Frames Per Second Intermittently

Aperture Size .218 x 2.25 inches—80 ft. film capacity
Built in timing light system (Camera above has optional 25 Light Timer)
Rigid construction makes camera ideally suited for Aircraft use.

OTHER CAMERAS AVAILABLE

All cameras listed below are equipped with registration pins

70MM-1B

FRAME SIZE: .218 x 2.218 inches
MAXIMUM FRAME RATE: 400 frames per sec.
FILM LOAD: 400 or 1000 ft. magazine

70MM-5A
For Aircraft Use

FRAME SIZE: 1.156 x 2.25 inches
MAXIMUM FRAME RATE: 60 frames per sec.
FILM LOAD: 400 ft. daylight loading spool

70MM-5B

FRAME SIZE: 1.156 x 2.25 inches
MAXIMUM FRAME RATE: 80 frames per sec.
FILM LOAD: 400 or 1000 ft. magazine

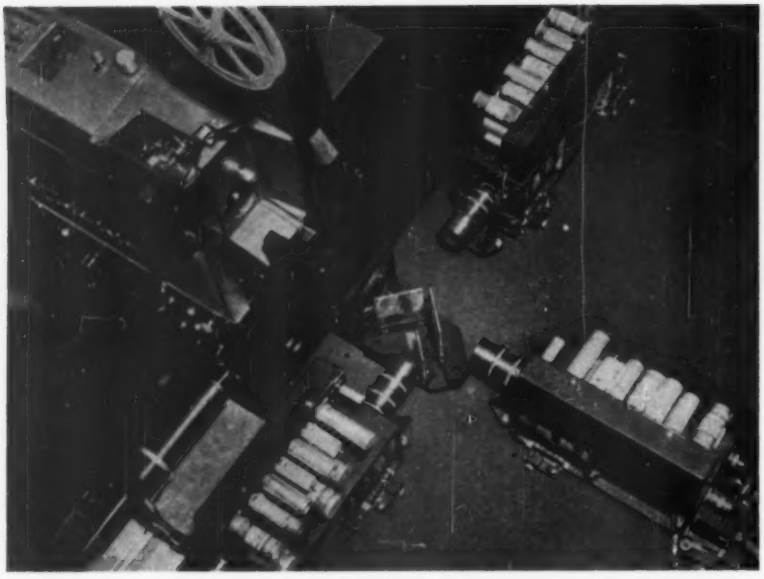
70MM10A

FRAME SIZE: 2.25 x 2.25 inches
MAXIMUM FRAME RATE: 60 frames per sec.
FILM LOAD: 400 or 1000 ft. magazine

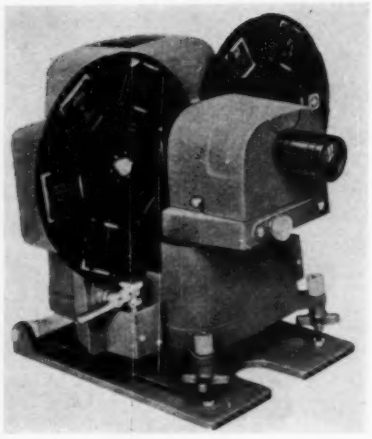
Additional information on request

PHOTO-SONICS INCORPORATED

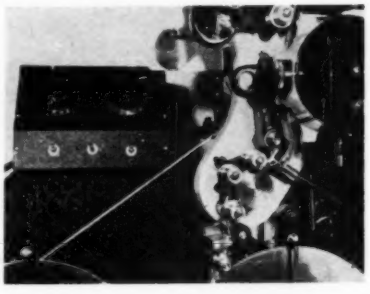
2704 West Olive Avenue, Burbank, California



This new RCA "3-V" Camera for televising color motion-picture films and slides uses three RCA Vidicon pickup tubes and a light-splitting optical system in the arrangement illustrated by this developmental model. The color image produced by the projector at the upper left is focused on the first of two dichroic mirrors mounted at angles in front of the projector. The first light-splitting mirror reflects the blue portions of the image to the Vidicon at upper right, but transmits the red and green portions to the second mirror which transmits the green picture elements to the Vidicon at lower right, but reflects the red portions to the one at lower left. The small vertical element mounted between the second mirror and the lens of the Vidicon at lower left is a filter which screens out unwanted infrared wavelengths and passes only the visible red light.



The Gray 3-B Single Lens Telojector is a newly designed projector for 35mm transparent slides in television stations, available from the Gray Research and Development Co., 658 Hilliard St., Manchester, Conn. It comes equipped with either a 6-in. or 7½-in. coated projection lens. Main power required for the unit is 115-v, 60-cycle, a-c with 300-w maximum. The control circuit operates from 24-v d-c, 10-w maximum; and two 150-w projection lamps operate at reduced voltage. The unit's system superimposes two images on one optical axis, to permit smooth lap dissolves and rapid switching. Pushbutton operation is either remote or local, with automatic changes through a sequence of 12 slides. It is designed for easy substitution of additional loaded turrets. The unit weighs about 35 lb and is 14½ in. high, 18½ in. wide and 16 in. or 19 in. long, depending on the lens.



A cuing device for "metallic cuing" to obviate edge notching is being offered by the Motion Picture Printing Equipment Co., Skokie, Ill. The unit is an electronic, two independent-channel relay which will operate the light shutter or light control board on one channel and the fade unit or color filter change unit on the second channel. It is designed so that, by setting the dial, the timing distance can be controlled from 32 frames to 10 frames. In the illustration, the cuing head, which mounts on the printer, may be seen on the right. The head shown is designed for the Bell & Howell 16mm Model J Printer. It is designed as a package unit for ease of installation. The cuing device is $279.00 f.o.b. the plant.

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The Only 16mm Camera with MIRROR REFLEX SHUTTER for Continuous Thru-the-Lens Focusing and Viewing.

The Arriflex 16 is the most advanced camera in the 16mm field. No comparison can be made with any existing equipment. It is in a class by itself... unique for its features, and outstanding for its workmanship.

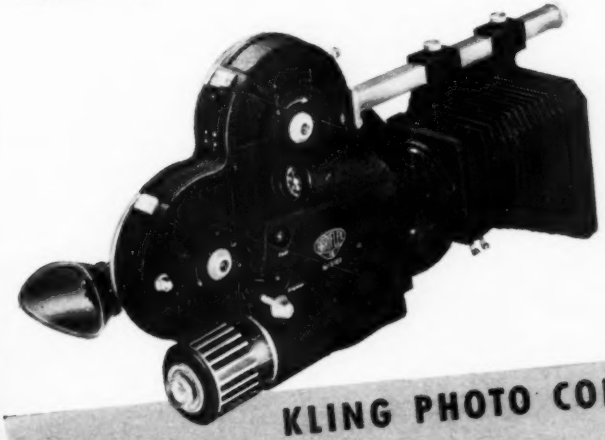
THESE ARE THE SENSATIONAL FEATURES OF THE ARRIFLEX 16

MIRROR REFLEX SHUTTER The most exciting feature of them all: for accurate framing and critical follow-focus, through the taking lens, even during the actual shooting. Image on ground glass is brilliant, uninverted and right-side-up, magnified 10x through a highly corrected optical system. No parallax, and no need for accessory finders.

REGISTRATION PIN Found only in cameras selling for $3000 or more. Automatically engages and locks film during exposure. Assures absolute frame registration, and picture steadiness.

ELECTRIC MOTOR DRIVE No need to stop a scene to wind a spring. Has variable-speed 6-volt DC motor with forward and reverse switch. Operates from portable, rechargeable battery pack, dry cell batteries, or with Transformer-Rectifier Unit on 115 volts AC. Easily interchangeable with Synchronous Motor Unit (available as accessory).

DIVERGENT 3-LENS TURRET Accommodates lenses from 11.5mm extreme wide angle to longest telephotos. Lenses quickly interchangeable. Wide angle and 300mm telephoto can be mounted simultaneously without mechanical or optical interference.



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FOOTAGE & FRAME COUNTERS — for forward and reverse action.

TACHOMETER — indicates speeds from 1 to 50 frames-per-second.

CONTOUR GRIP — provides a natural and firm grip for handheld shooting.

DETACHABLE NECKSTRAP — for handheld filming.

LIGHTWEIGHT — camera with Matte Box weighs only 7½ pounds.

FILM CAPACITY — 50 and 100-foot standard daylight spools.

400-FOOT MAGAZINE — accommodates External Film Magazine. (This accessory will be available at a later date.)

DETACHABLE MATTE BOX-FILTER HOLDER —has stationary and rotating filter stages for color filters, polarizing filters, fades, dissolves, and other effects.

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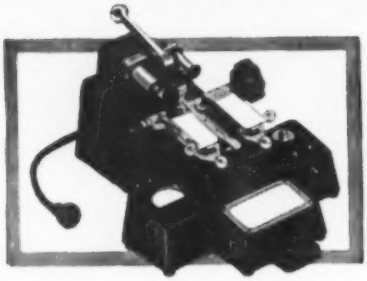

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Sample splice and Brochure on request.

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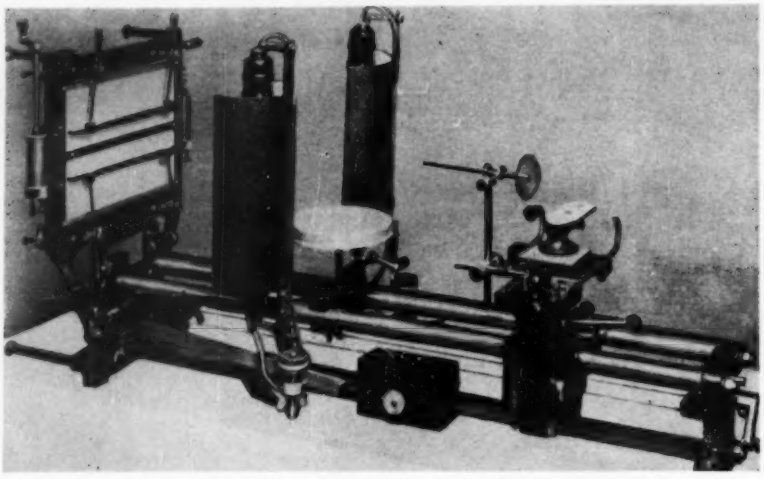

This Titler and the accompanying Special Effects Kit have been introduced by S.O.S. Cinema Supply Corp., 602 W. 52 St., New York 19. There are three models, TG-II, TG-III and TG-IV, with title boards $5\frac{1}{4} \times 7\frac{1}{8}$ in. or $7\frac{1}{8} \times 9\frac{1}{2}$ in. and with varying weights of construction. The largest measures 40 × 15 × 12 in. and weighs 40 lb. All are designed for table top use.

Designed for use on a wide range of titles, trick films, cartoons and animation, the table is adjustable north, east, south and west. Front and rear illumination are provided. Accessories included are: title card frame with platens, distance scale for setting camera lens, climbing and running title devices, turntable for rotating small objects and optical axis attachment. Prices are from $159.50 to $295.00.

A Standard Playback Characteristic for Lateral Disk Recording has been published as a tentative standard, AES T-1 dated December 21, 1953, by the Audio Engineering Society, which is submitting it to the American Standards Association. Committee Z57 of ASA now has it under consideration. William H. Offenhauser, Jr., is chairman of the AES Standards Committee. Reprints of this Tentative Standard are available at nominal cost from the AES at P.O. Box 12, Old Chelsea Station, New York 11.

American Standard Letter Symbols for Acoustics, ASA Y10.11-1953, contains more than one hundred symbols for terms used in acoustics measurements. Harry F. Olson, RCA Laboratories, Princeton, N.J., chaired the group which prepared the list. The standard may be obtained for $1.00 from the Order Dept., American Society of Mechanical Engineers, 29 W. 39 St., New York 18. Discounts are available for quantity orders.

The Society of Cinema Collectors and Historians has completed its first year and is planning a meeting and exhibition in the New York area in September, after which its first Journal will be published, with information of meetings, findings and personnel. Members are being sought among historians and students of the cinema and those associated with the motion-picture industry in production, writing or collecting. Membership application and brochure are available from the Secretary, Saul Haber, 4221 4th St., S.E., Washington, D.C.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Photographic Engineer: M.A.; age, 28. Desires challenging, responsible position where technical knowledge and ingenuity will be fully utilized; 8 yrs diversified experience pertaining to the photographic process, with particular emphasis on photographic instrumentation for data recording. Background includes a thorough working knowledge of electronics, the graphic arts, color, machine-shop practice, high-speed photography, etc. Presently engaged as a senior member of a well-known industrial research organization where all kinds of photographic techniques are used as research and service tools. Willing to relocate. Write: P.O. Box 259, New York 36.

Cameraman and special effects producer: For news, educational or advertising films; technical and musical education; camera and 35mm film strip and color development experience. Write: Vitold Bredshnyder, 812 N. Monroe St., Monroe, Mich.

Positions Available

16mm Printers, Color Timer, Negative Conformer: Permanent positions for qualified, experienced personnel. Company benefits. Send complete information and small photograph to Byron, Inc., 1226 Wisconsin Ave., Washington 7, D.C.

Photographer (Motion-Picture Animation), GS-9: Require 5 yr experience in photography, 4 yr of it as animation photographer in production of cel animation work in motion-picture production. Also included must be at least 1 yr in technical animation photography. $5060/yr. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or deliver completed to Civilian Personnel Div., Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City, N.Y.

Permanent Employment: Open for mechanical engineers or physicists with at least 1 yr optics experience. Knowledge of camera mechanism, auxiliary timing apparatus and control equipment, precision camera mounts, photography and a general overall knowledge of fundamental optics highly desirable. Positions are located near Cocoa, Fla., at RCA Missile Test Project. Send completed résumés or requests for applications to Harold D. Storz, Employment Sec., RCA Service Co., Box 11, O M U, Patrick AFB, Fla.

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NEXT MONTH'S JOURNAL will have this paper, with illustrations in color

"Subject Lighting Contrast for Color Photographic Films in Color Television," by F. T. Percy and T. Gentry Veal

Journals Available and Wanted

These notices are published as a service to expedite disposal and acquisition of out-of-print Journals. Please write direct to the persons and addresses listed.

Available

Journals from July 1948 through December 1954, including symposia, discussions, indexes, etc. Excellent condition. $50.00 FOB. Write Hal Fitzgerald, 4812 Cedar Lane, Hyattsville, Md.

Dec., 1936; Jan., Feb., Apr., May, July, Sept., Nov. 1937; 1938 complete; 1939 complete; 1940 complete; June-Aug. 1941. Write Richard S. Horton, Warner Horton Inc., 625 Madison Ave., New York 22.

Collection of back issues available either singly or as a lot. Write P. H. Cole, 1350 So. Bynside Ave., Los Angeles 19.

Wanted

Complete set of Transactions. Write John Pierp, Eastman Kodak Co., 343 State St., Rochester 4, N.Y.

High-Speed Photography, Volumes 1, 2 and 3. Write John Gunther, Armour Research Foundation, Technology Center, Chicago 16.

Transactions Nos. 4 and 9. Write W. W. Hennessy, 508 West 41 St., New York.

Signal Corps Pictorial Center could use a complete set of Journals, preferably as a donation. Write John P. Byrne, Motion Picture Specifications, Signal Corps Pictorial Center, 45-15 48 St., Long Island City 4, N.Y.

Transactions Nos. 1, 5, 6, 7 and 9. Write Lloyd E. Varden, Pavelle Color, Inc., 330 West 57 St., New York 19.

Meetings

Biological Photographic Association, Annual Meeting, Aug. 25–27, Chalfonte-Haddon Hall, Atlantic City.

Illuminating Engineering Society, National Technical Conference, Sept. 13–17, Chalfonte-Haddon Hall, Atlantic City, N. J.

3rd International Symposium on High-Speed Photography, Paris, September 22–28, 1956. Arranged by the Association Francaise des Ingenieurs et Techniciens de Cinema. Applications or inquiries should be addressed to the Secretary of the Organization Committee, P. Nouille, Laboratoire Central de Prevoyance, Fort de Montrouge, Arcueil (Seine), France.

National Electronics Conference, Tenth Annual Conference, Oct. 4–6, Hotel Sherman, Chicago.

Photographic Society of America, Annual Meeting, Oct. 5–9, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers Fall General Meeting, Oct. 11–15, Chicago, Ill.

75th Semiannual Convention of the SMPTE, Oct. 10–22, Ambassador Hotel, Los Angeles.

Theatre Equipment and Supply Manufacturers' Association (T.E.S.M.A.), Annual Trade Show, with exhibits, Oct. 31–Nov. 2, Conrad Hilton Hotel, Chicago.

Adult Education Association, National Conference, Nov. 8–10, Hotel Morrison, Chicago.

National Electrical Mfrs. Assn., Nov. 9–11, Haddon Hall Hotel, Atlantic City, N. J.

77th Semiannual Convention of the SMPTE, Aug. 29–Sept. 2, 1955, Drake Hotel, Chicago.

The International Commission on Illumination is to hold its next international conference in Zurich, Switzerland, June 15–22, 1955. Offers of papers should be addressed to the Chairman of the Papers Committee, A. A. Brainerd, 1015 Chestnut St., Philadelphia 7. Manuscripts must be in the hands of the Central Bureau between Oct. 1 and Dec. 31, 1954.

Biological Photographic Association, Annual Meeting, Aug. 30–Sept. 2, 1955, Wisconsin Hotel, Milwaukee.

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955 (new year), Lake Placid Club, Essex County, N.Y.

Photographic Society of America, 1955 Convention, Oct. 5–8, 1955, Statler-Penn Hotel, Boston, Mass.

SMPTE Officers and Committees: The names of the Officers of the Society, its Sections, Subsections and Chapters, and of the Committee Chairmen and Members were published in the April Journal.

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